This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Losses in boiling vegetables and the composition and digestibility of ...

Harry Snyder, Almah Jane Frisby, Arthur Peyton Bryant

A 10.3: no 43

THEODORE HOUGH
UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VA.

BULLETIN NO. 43. 212.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS.

THEODORE HOUGH
UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VA.

LOSSES IN BOILING VEGETABLES

AND THE

COMPOSITION AND DIGESTIBILITY OF POTATOES AND EGGS.

BY

H. SNYDER, B. S., ALMAH J. FRISBY, M. D., AND A. P. BRYANT, M. S.[1]

1862 1889

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1897.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 15, 1897.

SIR: I have the honor to transmit herewith a report on the loss of nutrients in boiling potatoes, carrots, and cabbage, and the composition and digestibility of potatoes and eggs, by Prof. H. Snyder, Almah J. Frisby, M. D., and A. P. Bryant, M. S. These investigations constitute a part of the inquiries made with the funds appropriated by Congress "to enable the Secretary of Agriculture to investigate and report upon the nutritive value of the various articles and commodities used for human food," and were carried on under the supervision of Professor Atwater, special agent in charge of nutrition investigations, in accordance with instructions given by the Director of this Office.

The greater part of the food of man is prepared for use by cooking, yet the changes which various foods undergo during the process and the losses which are brought about by cooking have been little studied. This question has a wide practical application as well as scientific interest. In determining the nutritive value of various articles of food, digestibility is an important consideration. Perhaps no feature of the subject is more discussed. Nevertheless very few experiments with man to determine the digestibility of various foods have been made. Almost all information has been derived from artificial digestion experiments which approximate more or less closely digestion in the body. It is by no means certain that the two processes give the same results. Digestion experiments with man were believed to be necessary, and a diet in which potatoes were the chief ingredient was selected for experimental purposes.

Professor Snyder's work was carried on in the laboratory of the College of Agriculture of the University of Minnesota; that of Dr. Frisby and Mr. Bryant in the chemical laboratory of Wesleyan University, Middletown, Conn.

This report is respectfully submitted, with the recommendation that it be published as Bulletin No. 43 of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

Page.

Loss of nutrients in boiling potatoes, carrots, and cabbage. By H. Snyder, B. S 7
  Introduction 7
    The three principal classes of nutrients in foods 7
    The effect of cooking on the nutrients of foods 8
  Experiments with potatoes 9
    Composition of potatoes 9
    Cooking tests 11
    Discussion of results 13
    Conclusions 14
  Experiments with carrots 15
    Composition of carrots 15
    Cooking tests 15
    Conclusions 17
  Experiments with cabbage 17
    Composition of cabbage 17
    Cooking tests 18
    Conclusions 19
  General summary 19
The digestibility of potatoes and eggs. By H. Snyder, B. S 20
  Introduction 20
  Digestibility of boiled eggs in pepsin solution 20
  Digestion experiment on man with a diet of potatoes, eggs, milk, and cream 21
  Discussion of results 23
The composition of different parts of the potato and the loss of nutrients during the process of boiling. By Almah J. Frisby, M. D., and A. P. Bryant, M. S 25
  Introduction 25
  Composition of different parts of the potato 26
    Sampling 26
    The analyses 27
    The protein factor 28
    Amount of solid matter in the juice of the potato 29
  Loss of nutrients in boiling 29
    Conclusions 31

ILLUSTRATIONS.

Page.

FIG. 1. Cells of a raw potato with starch grains in natural condition........ 8

2. Cells of a partially cooked potato.. 8

3. Cells of a thoroughly boiled potato 9

4. The composition of the potato and the loss of nutrients when boiled with the skin removed 14

5. The composition of the carrot and the loss of nutrients when boiled.. 17

6. The composition of the cabbage and the loss of nutrients when boiled. 19

7. Transverse and longitudinal sections of the potato..................... 25

LOSSES IN BOILING VEGETABLES, AND THE COMPOSITION AND DIGESTIBILITY OF POTATOES AND EGGS.

LOSS OF NUTRIENTS IN BOILING POTATOES, CARROTS, AND CABBAGE.

By H. Snyder, B. S.,
Chemist, Minnesota Agricultural Experiment Station, and Professor of Agricultural Chemistry, College of Agriculture, University of Minnesota.

INTRODUCTION.

THE THREE PRINCIPAL CLASSES OF NUTRIENTS IN FOODS.

The nutritive ingredients of foods are commonly divided into three general classes, namely, nitrogenous substances to which the general term protein is applied, fats, and carbohydrates.

The nitrogenous substances.—The nitrogenous substances include (1) the albuminoids, of which egg albumen is a well-known example; (2) the so-called gelatinoids, of which gelatin may serve as a type; and (3) the amids; i. e., synthesis and cleavage products of various kinds.

The vegetable albuminoids are to a large extent different from those found in animal foods. They appear to be more variable in composition, and less is known concerning their chemical composition, structure, and digestibility.

The fats.—The amount of dry matter dissolved out of a substance by continuous treatment with ether is designated as fat. It forms a large part of animal foods, but in vegetable foods, with the exception of some seeds and nuts, the proportion is very small.

The carbohydrates.—This class includes the sugars, starches, woody fibers, cell walls, etc., of the vegetable foods. Carbohydrates are found in but few animal foods, with the exception of milk, and when present are in very small quantities. In vegetable foods, on the contrary, they form the major part of the nutritive matter. The principal constituent of vegetable carbohydrates is starch. The starch grains are usually inclosed in thin cells, the walls of which may be composed of more or less fibrous material.

The digestibility of the carbohydrates depends upon the proportion of sugar and starches to cell walls or fiber. The sugars are more easily digested than the starches, since the latter must be changed to sugar in the process of digestion before it can be assimilated by the body. Both the starches and the sugars, however, are probably completely digested, but the cell walls, the framework of the substance, are not so easily digested; in fact, while 98 to 100 per cent of the starches and sugars may be digested, the digestibility of these cell walls, or fiber as it is called, may vary all the way from 30 to 70 per cent.

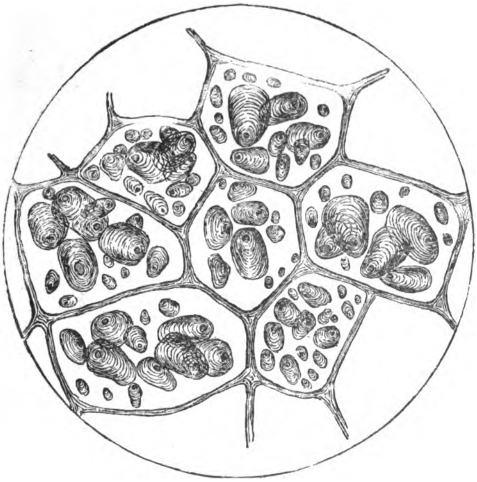


FIG. 1.—Cells of a raw potato with starch grains in natural condition.

THE EFFECT OF COOKING ON THE NUTRIENTS OF FOODS.

Some of the albuminoids are soluble in water, and nearly all in dilute saline solutions. Heating coagulates the albuminoids and renders them insoluble. Cooking, therefore, preserves albuminoids from loss. If meat is put into cold water and then brought to the boiling point more or less of the albuminoid material will be dissolved and some of the most expensive part of the food will be lost unless the soup is utilized also. If put directly into hot or boiling water the soluble albuminoids on the surface will be coagulated, and this loss will be largely prevented.[1] The same principle is probably applicable to vegetables also.

Besides rendering soluble albuminoids insoluble, cooking makes others of the nitrogenous substances more digestible, and in the case of meats loosens the fibers of connective tissue, rendering it tender and more palatable. Unless the degree of heat is great enough to cause scorching, fats are doubtless little affected by cooking.

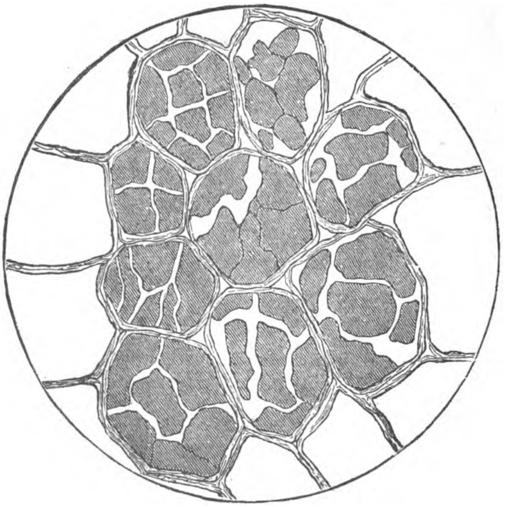


FIG. 2—Cells of a partially cooked potato.

The carbohydrates are much more easily digested in the cooked than in the raw state. In the raw food the sugars and starches are inclosed in cells. Very little of the cellulose of the cell walls is digested by man. The cell contents, therefore, are often excreted unchanged. Cooking bursts these cell walls, thus exposing the inclosed sugars and starches to the action of the digestive juices. The starch granules also swell up and burst on cooking, exposing more surface to be acted upon. Starch is to a slight extent changed to dextrin by dry heat, and possibly, also, by heating with water. Since the majority of vegetable foods, however, consist largely of starches and have very little sugar in them, the loss of carbohydrates would presumably not be very great during boiling.

---

[1] U. S. Dept. Agr., Farmers' Bul. 34.

The effect of boiling upon the cells of the potato is shown in figs. 1, 2, and 3.[1]

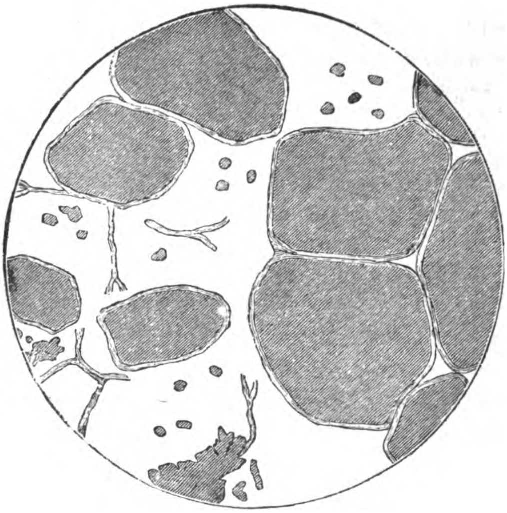


FIG. 3.—Cells of a thoroughly boiled potato.

Several years ago Katherine Williams reported[2] an extended study of the composition of a number of cooked and a few raw vegetables. Ultimate and proximate analyses of the various vegetables were made and the fuel value determined. Many cooked vegetables have been analyzed in connection with the food investigations undertaken by this Department and by other investigators.

Comparatively few attempts have been made to learn the changes which take place in vegetable foods on cooking, or the extent of these changes. As the water in which vegetables are boiled is usually thrown away, any matter which was in solution would be wasted. Experiments were therefore undertaken with potatoes, carrots, and cabbage for the purpose of studying the loss of nutrients when boiled, under a number of different conditions. These vegetables were selected as the best representatives of tubers, roots, and pot herbs.

EXPERIMENTS WITH POTATOES.

COMPOSITION OF POTATOES.

According to Lawes and Gilbert,[3] the composition of the flesh of the potato differs from that of the juice. Although the flesh contains 85 per cent of the total water-free substance, it contains but 15 per cent of the nitrogen. The remainder, 85 per cent, is in the juice. Of this 49 per cent is in the form of albuminoid and 36 per cent in the form of nonalbuminoid nitrogen.

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 88; from Märcker's Studien in der Spiritusfabrikation.

[2] Jour. Chem. Soc. [London], 61 (1892), p. 226.

[3] "On the growth of the potato," p. 26, Rothamsted Memoirs, vol. 6.

The proportion of albuminoid and nonalbuminoid nitrogen varies greatly according to different writers. E. Schulze and Barbieri[1] and E. Schulze and E. Eugster[2] give, as the result of five analyses, from 35 to 56 per cent of nonalbuminoid nitrogen. O. Kellner[3] gives 44 to 58 per cent of nonalbuminoid nitrogen, and A. Morgen[3] from 30 to 52 per cent, making 45 per cent as a fair average of the amount of nonalbuminoid nitrogen and 55 per cent for the amount of albuminoid nitrogen present in potatoes. In the experiments here reported the figures obtained were nearly the reverse of these latter, as the average of the two analyses made gave 40 per cent of albuminoid and 60 per cent of nonalbuminoid nitrogen (see also p. 29). It is evident that in boiling the loss of a considerable portion of this albuminoid nitrogen may occur.

There is also a possibility of loss of inorganic and organic salts during cooking. Probably about 85 per cent of the potash of the potato, as well as the larger part of the citric acid, is in the juice. The total amount of citric acid, however, is small. While potash salts and citrates have no real nutritive value, they appear to be of some considerable medicinal or tonic value and give "relish" to the food. No attempt was made to determine the loss of fat and fiber in boiling. It would be presumably, very small.

Three experiments on the effect of cooking on the composition of potatoes were made. In the first experiment (A) the skins were removed and the potatoes soaked three and five hours, respectively, and cooked in distilled water, which was cold at the beginning of the test. In the second experiment (B) the skins were removed and the potatoes, without previous soaking, were cooked in (1) distilled water (soft water), (2) alkaline water, (3) limewater (hard water), which was in each case cold at the beginning; in (4) distilled water, (5) alkaline water, and (6) limewater, which was in each case hot at the beginning of the test. In the third experiment (C) the potatoes were not peeled and were cooked without previous soaking in distilled, alkaline, and limewater, which was cold at the beginning of the test, and in distilled, alkaline, and limewater, which was hot at the beginning of the test.

About two bushels of potatoes of a uniform character were divided into lots of about a kilogram ($2\frac{1}{5}$ pounds) each. An analysis was made of the whole potato, including the skin. This was assumed to represent the composition of all the potatoes used in the experiments except those which were soaked before boiling. In this latter case half of each of the peeled potatoes used in the experiment was taken as a sample and analyzed.

---

[1] Landw. Vers. Stat., 21 (1878), p. 63.

[2] Ibid., 27 (1882), p. 357.

[3] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., II, p. 631.

The methods of analysis used were substantially those adopted by the Association of Official Agricultural Chemists, and were as follows:

Nitrogen.—In order to ascertain the relative proportion of albuminoids and extractives or amids the nitrogen was determined, (1) as the total nitrogen by the Kjeldahl method, and (2) the albuminoid nitrogen by the Stutzer method. The results for albuminoid nitrogen are without doubt too low, as the copper proteid dissolved to a slight extent in the moderately warm solution when filtered and separated out on standing. If filtered when cold the filtration was so slow that fermentation, with a consequent loss of the copper proteid, would begin before the filtration was completed.

Starch.—Starch was determined by inversion with boiling hydrochloric acid and water and estimating the amount of copper in Fehling's solution precipitated by the resulting dextrin.

Fat, fiber, and ash.—These were determined in the usual way in the fresh material.

The accompanying table shows the composition of the potatoes used in these experiments, and gives also the composition as obtained by former analyses at the University of Minnesota,[1] the average of all American analyses,[2] and the average of European analyses.[3]

Composition of potatoes.

	Number of analyses.	Water.	Albuminoid nitrogen.	Total nitrogen.	Protein.	Fat.	Carbohydrates.			Ash.
							Fiber.	Starch.	Nitrogen-free extract. [a]	
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Used in Experiment A	1	78.0	0.15	0.35	2.2	....	....	....	....	0.9
Used in Eperiments B and C	1	77.2	.15	.40	2.5	0.1	0.2	16.4	19.3	.9
Average other Minnesota analyses	20	75.5	.20	.40	2.5	.1	.3	19.9	20.9	1.0
Average all American analyses	86	78.0	....	....	2.2	.1	....	....	18.8	.9
Average European analyses	178	75.0	[b] .19	.34	2.1	.1	.7	....	21.7	1.1

[a] 100 less the sum of the percentages of water, protein, fat, and ash.
[b] Calculated, allowing 45 per cent to be albuminoid.

COOKING TESTS.

The potatoes were boiled in a metal kettle over a gas flame at about the same rate as when cooked in the kitchen. The uncooked potatoes were weighed, and the water in which they were cooked was also weighed and analyzed. The total amounts of dry matter, albuminoid nitrogen, total nitrogen, starch, and ash that were removed in cooking 100 parts of fresh potatoes was then calculated. The results of each of the three experiments are given in the following table:

---

[1] Minnesota Sta. Bul. 42.

[2] From an unpublished compilation of analyses of American food products.

[3] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., II, p. 626.

Loss of matter in cooking potatoes.

Method of preparation and cooking.	Weight of potatoes used.	Loss of matter in fresh potatoes.					Percentage loss of each constituent.				
		Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Starch.	Ash.	Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Starch.	Ash.
A. Skins removed; soaked before cooking.											
	Grams.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Soaked 3 hours; distilled water, cold at start.........	753	1.45	0.035	0.161	......	0.41	6.6	23.3	46.0	......	45.6
Soaked 5 hours; distilled water, cold at start.........	603	1.40	.040	.202	......	.28	6.4	26.7	57.7	......	31.1
Average...............	....	1.43	.038	.181	......	.35	6.5	25.0	51.8	......	38.3
B. Skins removed; not soaked.											
Distilled water, cold at start.	943	.63	.007	.055	0.16	.18	2.8	4.7	13.8	1.0	19.6
Do	939	.74	.006	.080	.16	.15	3.2	4.0	20.0	1.0	16.3
Average	....	.68	.006	.068	.16	.16	3.0	4.3	16.9	1.0	17.9
Alkaline water, cold at start.	1,165	.68	.016	.055	.15	.17	3.0	10.7	13.8	.9	18.5
Do	952	.67	.011	.061	.19	.17	2.9	7.3	16.7	1.2	18.5
Average	....	.67	.014	.065	.17	.17	2.9	9.0	15.2	1.0	18.5
Limewater, cold at start	907	.70	.011	.055	.14	.18	3.1	7.3	13.8	.9	19.6
Do	979	.79	.015	.067	.17	.19	3.5	10.0	16.7	1.0	20.6
Average	....	.75	.013	.061	.16	.19	3.3	9.0	15.3	1.0	20.1
Average of 6 tests starting with cold water ..	....	......	......	......	......	......	3.1	7.3	15.8	1.0	18.8
Distilled water, hot at start..	939	.72	......	.033	.11	.17	3.2	......	8.2	.7	18.5
Do	1,052	.52	.004	.027	.10	.08	2.3	2.7	6.7	.6	8.7
Average	....	.62	.004	.025	.10	.13	2.8	2.7	7.5	.6	13.6
Alkaline water, hot at start..	988	.71	.003	.033	.17	.19	3.1	2.0	8.3	1.0	20.7
Do	970	.80	.004	.041	.19	.22	3.5	2.7	10.2	1.2	23.9
Average	....	.76	.003	.037	.18	.21	3.3	2.3	9.2	1.1	22.3
Limewater, hot at start......	952	1.15	.006	.024	.26	.15	5.1	4.0	6.0	1.6	16.3
Do	1,043	.78	.007	.038	.17	.19	3.4	4.7	9.5	1.0	20.7
Average	....	.96	.006	.031	.22	.17	4.2	4.3	7.8	1.3	18.5
Average of 6 tests starting with hot water...	....	......	......	......	......	......	3.4	3.2	8.2	1.0	18.1
C. Skins not removed.											
Distilled water, cold at start.	943	.14	Trace	.005	......	.03	.6	.3	1.2	......	3.3
Do	952	.11	Trace	.004	......	.07	.5	.1	1.0	......	7.6
Average	....	.13	Trace	.005	......	.05	.6	.2	1.1	......	5.4
Alkaline water, cold at start.	988	.08	Trace	.004	......	.03	.4	.3	1.0	......	3.3
Do	1,034	.12	Trace	.005	......	.04	.5	.3	1.2	......	4.3
Average	....	.10	Trace	.005	......	.04	.5	.3	1.1	......	3.8
Limewater, cold at start	1,474	.04	.002	.003	......	.01	.2	1.3	.7	.1	1.1
Do	1,165	......	.002	.003	......	......	......	1.3	.8	.1	......
Average	....	.04	.002	.003	......	.01	.2	1.3	.8	.1	1.1
Average of 6 tests starting with cold water ..	....	......	......	......	......	......	.4	.6	1.0	.1	3.4

Loss of matter in cooking potatoes—Continued.

Method of preparation and cooking.	Weight of potatoes used.	Loss of matter in fresh potatoes.					Percentage loss of each constituent.				
		Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Starch.	Ash.	Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Starch.	Ash.
C. Skins not removed—Cont'd.	*Grams.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Distilled water, hot at start	1,047	0.15	0.001	0.005	......	0.05	0.7	0.5	1.3	......	5.4
Do	1,075	.16	.001	.008	......	.04	.7	.5	2.0	......	4.4
Average	....	.16	.001	.006	......	.05	.7	.5	1.6	......	4.9
Alkaline water, hot at start	1,229	.10	trace.	.003	......	.03	.4	.2	.8	......	3.2
Do	1,034	.09	trace.	.003	......	.02	.4	.2	.8	......	2.2
Average	....	.10	trace.	.003	......	.03	.4	.2	.8	......	2.7
Limewater, hot at start	1,075	.04	.001	.002	0.01	.02	.2	.4	.5	0.1	2.2
Do	848	.06	.001	.003	.01	.02	.3	.5	.8	.1	2.2
Average	....	.05	.001	.002	.01	.02	.2	.5	.7	.1	2.2
Average of 6 tests starting with hot water	....	......	......	......	......	......	.4	.4	1.0	.1	3.3

The weight of each ingredient removed divided by the total weight of the same ingredient in the fresh potatoes before cooking gives the percentage of loss of that substance. These figures are shown in the last five columns of the table. The same composition was assumed for the peeled potatoes used in Experiment B as for the whole potatoes used in Experiment C. This may not be strictly accurate, since it presupposes the uniform composition of all parts of the potato. As shown on page 27, there is a slight variation between the composition of the interior and the part peeled off, but this probably is not great enough to have a material effect upon the results obtained.

DISCUSSION OF RESULTS.

By reference to the table (p. 12) it will be seen that, as might be expected, the greatest loss occurs when the potatoes are peeled and soaked in cold water before boiling. In this case the loss of nitrogenous matter was from 46 to 58 per cent, depending upon the length of time they were soaked. Of the albuminoids 25 per cent and of the mineral matters 38 per cent were extracted by the water in which the potatoes were cooked. The water would ordinarily be thrown away and this material lost.

When the potatoes are peeled and put into cold water, and heated to boiling as soon as possible, the loss is much smaller, being about 16 per cent of the total nitrogenous matter (of which albuminoids form a trifle less than half) and about 19 per cent of the total mineral matter. When the potatoes are peeled and put directly into boiling water the loss of albuminoid and other nitrogenous matter is only about half that of the last case, but the amount of mineral matter is practically the same. The boiling water soon coagulates the albuminoids on the surface of the potato, rendering them insoluble. They fill the outer pores of the potato, rendering the inner juices less liable to loss, although not before a considerable amount of the salts or mineral matter has escaped. The relative amount of nonalbuminoid nitrogen lost is greater than when the potatoes are put into cold water at the start. There seemed to be but little difference as regards total nitrogenous matter, starch, and ash, whether distilled, alkaline, or limewater was used. The limewater, however, seemed to have a greater solvent action upon the albuminoids than did the distilled or alkaline waters. The solvent action of cold alkaline water was somewhat greater than that of distilled water. Inasmuch as the albuminoid material of the potato is a globulin,[1] and globulins are insoluble in pure water but soluble in saline water, this also is what would be expected. The salts in solution in the juice of the potato doubtless carry the globulin in solution to some extent, thus rendering a loss possible even in pure distilled water.

The loss in boiling peeled potatoes is shown in graphic form in figure 4.

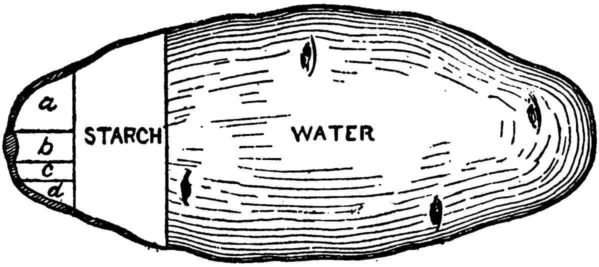


FIG. 4.—The composition of the potato and the loss of nutrients when boiled with the skin removed: *a*, fiber, pectose, fat, etc.; *b*, nonalbuminoid nitrogenous matter; *c*, albuminoid nitrogenous matter; *d*, mineral matter. The hatched portion represents the loss.

It will be seen from the table that when the potatoes are unpeeled the loss of matter is very inconsiderable, less than 1 per cent of the albuminoid matter, only 1 per cent of the total nitrogenous matter, hardly a trace of starch, and but a little over 3 per cent of the mineral matter being extracted. The different kinds of water had no effect except on mineral matter. This was removed to a greater extent by the distilled water than by the alkaline or limewater.

CONCLUSIONS.

The conclusions drawn from these experiments may be briefly summarized as follows:

(1) In order to obtain the highest food value, potatoes should not be peeled before cooking.

(2) When the potatoes are peeled before cooking, the least loss is sustained by putting them directly into hot water and boiling as rapidly as possible. Even then the loss is very considerable.

---

[1] Osborne and Campbell, Connecticut State Sta. Rpt. 1895, p. 255 (E. S. R., 8, p. 371).

(3) If potatoes are peeled and soaked in cold water before boiling the loss of nutrients is very great, being one-fourth of all the albuminoid matter. In a bushel of potatoes the loss would be equivalent to a pound of sirloin steak.

EXPERIMENTS WITH CARROTS.

A series of experiments similar to those just described was undertaken with carrots. They were selected as fairly representative of the roots used for food. While in uncooked potatoes there is but a trace of sugar, such roots as beets, carrots, parsnips, etc., contain a considerable amount. This renders it probable at the outset that the loss in the cooking of carrots would be greater than in the cooking of potatoes.

COMPOSITION OF CARROTS.

Samples of the carrots used in the experiments were analyzed. The results of these analyses, as well as the average composition of carrots, including both American and European analyses, are shown in the following table:

Composition of carrots.

						Carbohydrates.					
	Water.	Albuminoid nitrogen.	Total nitrogen.	Protein.	Fat.	Cane sugar.	Fruit sugar.	Fiber.	Other carbohydrates.	Total carbohydrates. *a*	Ash.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Carrots used in experiments	87.5	0.08	0.18	1.1	(*b*)	3.6	3.0	(*b*)	4.0	*c*10.6	0.8
Average 17 American analyses *d*	88.2	......	......	1.1	0.4	......	......	......	......	9.2	1.1
Average 35 European analyses *e*	86.8	......	......	1.2	.3	2.1	4.1	1.5	3.0	10.7	1.0

a 100 less the sum of the percentages of water, protein, fat, and ash.
b Not determined.
c Includes fat.
d U. S. Dept. Agr., Office of Experiment Stations Bul. 28.
e König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., II, p. 649.

Although carrots contain less nitrogen than potatoes, they seem to contain relatively more albuminoid nitrogen and therefore to furnish more matter available for building muscular tissue. In the carrots used in the following experiments, 44.4 per cent of the total nitrogen was in the albuminoid form.

COOKING TESTS.

In preparing carrots (sliced or whole) for the table they are put into either hot or cold water and boiled until they are soft enough to be easily pierced with a fork. The water in which the carrots have been boiled is usually drained off and thrown away. This water is colored yellow and has a very sweet taste, plainly indicating that some of the sugar has been extracted and lost.

In order to determine how much food value was lost in boiling carrots under various conditions, twelve trials were made in which lime-water (hard water), alkaline water, and distilled water (soft water) were used. The carrots were prepared for cooking in the usual way by washing with a brush, scraping, drying quickly with a towel, and cutting into pieces. These pieces were wedge-shaped, usually about 4 inches long, and with three sides and a triangular base measuring about 1½ inches on a side. In some of the trials the pieces were cut smaller and in some larger in order to determine the effect of size on the loss of material. As in the experiments with potatoes, the water in which the carrots were cooked was hot at the beginning of the cooking period in some of the tests and cold in others. The carrots were boiled in a metal kettle over a gas flame under as nearly the usual conditions as possible The loss of matter in cooking 100 parts of fresh carrots and the percentages of each constituent lost in cooking under the various conditions are shown in the following table:

Loss of matter in cooking carrots.

Method of preparation and cooking.	Weight of carrots used.	Loss of matter in fresh carrots.					Percentage loss of each constituent.				
		Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Sugar.	Ash.	Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Sugar.	Ash.
A. Small pieces.	*Grams.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Alkaline water, hot at start..	358	3.68	0.006	0.063	2.18	0.31	29.4	7.5	35.0	33.0	41.3
Limewater, hot at start.......	349	3.81	.008	.078	1.14	.37	30.5	10.0	43.3	17.3	49.4
Distilled water, cold at start..	399	3.55	.009	.064	......	.31	28.4	11.3	35.6	......	41.3
Limewater, cold at start......	476	3.93	.010	.101	1.82	.43	31.4	12.5	56.1	27.6	57.3
Average	....	3.74	.008	.077	1.71	.36	29.9	10.3	42.5	26.0	47.3
B. Medium-sized pieces.											
Distilled water, hot at start..	494	2.93	.006	.048	......	.12	23.4	7.5	26.7	......	16.0
Do	480	3.70	.006	.047	......	.30	29.6	7.5	26.1	......	40.0
Limewater, hot at start.......	444	2.72	.005	.055	......	.34	21.7	6.3	30.6	......	45.3
Alkaline water, hot at start..	353	2.52	.006	.045	1.58	.33	20.2	7.5	25.0	23.9	44.0
Distilled water, cold at start..	580	2.68	.005	.050	......	.15	21.4	6.2	27.8	......	20.0
Alkaline water, cold at start..	503	2.47	.005	.047	......	.29	19.8	6.3	26.1	......	38.7
Do	403	3.61	.003	.055	1.92	.43	28.9	3.7	30.6	29.1	37.3
Average	....	2.95	.005	.050	1.75	.28	23.5	6.4	27.5	26.5	37.3
C. Large pieces.											
Limewater, cold at start......	499	2.52	.004	.036	1.02	.22	20.2	5.0	20.0	15.5	29.3

As will be seen, the character of the water makes little apparent difference in the amount of nutrients lost when carrots are boiled. The loss depends almost wholly upon the size of the pieces. The loss of mineral matter is large, being nearly one-half of the total amount in the case of the small pieces, and nearly one-third of the total when the pieces were large. The loss of nitrogenous matter and sugar is also very large. With small pieces about 40 per cent of the total nitrogen and 26 per cent of the total sugar is lost, or about 1 pound of sugar in a bushel of carrots. With medium-sized pieces the loss of nitrogen is 27 per cent and of sugar 26 per cent. With large pieces the loss of nitrogen is 20 per cent and of sugar 15 per cent. This latter loss is equivalent to over half a pound of sugar in a bushel of carrots. Of the total nutrients 30 per cent is lost from the small pieces, 24 per cent from the medium, and 20 per cent from the large pieces. In other words, as ordinarily cooked carrots lose one-quarter of their nutritive value. Figure 5 shows these losses graphically.

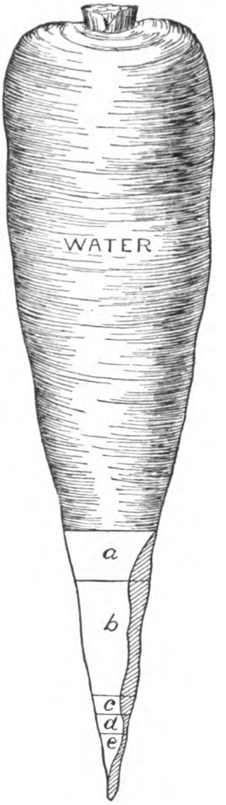


Fig. 5.—The composition of the carrot and the loss of nutrients when boiled: *a*, fiber, starch, fat, etc.; *b*, sugar; *c*, nonalbuminoid nitrogenous matter; *d*, albuminoid nitrogenous matter; *e*, mineral matter. The hatched portion represents the loss when medium-sized pieces were boiled.

CONCLUSIONS.

These trials suggest that in order to retain the greatest amount of nutrients in the cooking of carrots (1) the pieces should be large rather than small; (2) the boiling should be rapid in order to give less time for the solvent action of the water to act upon the food ingredients; (3) as little water as possible should be used; and (4) if the matter extracted be used as food along with the carrots, instead of being thrown away, the loss of 20 to 30 per cent, or even more, of the total food value may be prevented.

EXPERIMENTS WITH CABBAGE.

Experiments analogous to those with potatoes and carrots were made with cabbage to determine the loss of food material during the process of preparation for the table.

Cabbage may be taken as representing the class of pot herbs in which the leaves are the edible portion. It exposes more surface to the action of the water than do tubers or roots.

COMPOSITION OF CABBAGE.

The composition of the cabbage analyzed in connection with these experiments, as well as the average of American analyses of cabbage, is as follows:

Composition of cabbage.

	Water.	Albuminoid nitrogen.	Total nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Cabbage used in these experiments	92.5	0.11	0.18	1.1	0.5	0.7	0.7
Average of 7 American analyses [a]	90.3	....	....	2.1	.4	5.8	1.4

---

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 28.

It will be noticed especially that in cabbage there is, relatively, much more albuminoid material than in either potatoes or carrots, the albuminoid nitrogen amounting to 61 per cent of the total nitrogen.

COOKING TESTS.

The plan of the experiments was the same as that followed in the experiments with potatoes and carrots. In each trial half of a solid fair-sized cabbage was used. The cabbage was boiled in a metal kettle over a gas flame at about the same rate as on an ordinary cook stove. The following table shows the results obtained by the different methods of cooking:

Loss of matter in cooking cabbage.

Method of cooking.	Weight of cabbage used.	Loss of matter in fresh cabbage.					Percentage loss of each constituent.				
		Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Fat and carbohydrates.	Ash.	Dry matter.	Albuminoid nitrogen.	Total nitrogen.	Fat and carbohydrates.	Ash.
	Grams.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Distilled water, cold at start.	471.7	2.48	0.003	0.062	1.76	0.33	33.2	2.7	34.4	31.1	47.1
Do	390.1	2.69	.009	.055	2.01	.34	36.0	8.2	30.6	35.6	48.6
Average	......	2.58	.006	.058	1.88	.34	34.6	5.5	32.5	33.3	47.8
Alkaline water, cold at start.	326.6	3.17	.009	.081	2.39	.27	42.4	8.2	45.0	42.3	38.6
Do	317.5	3.08	.013	.065	2.37	.30	41.2	11.8	36.1	42.0	42.8
Average	......	3.12	.011	.073	2.38	.29	41.8	10.0	40.6	42.1	40.7
Limewater, cold at start	331.1	3.17	.005	.087	2.23	.40	42.4	4.6	48.3	39.5	57.1
Do	240.4	3.05	......	.078	2.20	.36	40.8	......	43.3	38.9	51.4
Average	......	3.11	.005	.083	2.22	.38	41.6	4.6	45.8	39.2	54.2
Average of 6 tests in cold water	......	......	......	......	......	......	39.3	6.7	39.6	38.2	47.6
Distilled water, hot at start	435.5	2.17	.005	.060	1.56	.23	29.0	4.6	33.3	27.6	32.9
Do	367.4	2.22	.008	.054	1.65	.23	29.7	7.3	30.0	29.2	32.9
Average	......	2.20	.007	.057	1.60	.23	29.4	6.0	31.7	28.4	32.9
Alkaline water, hot at start	317.5	2.70	.008	.057	2.13	.21	36.1	7.3	31.7	37.7	30.0
Do	263.1	2.79	.013	.076	2.04	.27	37.3	11.8	42.2	36.1	38.6
Average	......	2.75	.011	.067	2.09	.24	36.7	9.6	37.0	36.9	34.3
Limewater, hot at start	330.7	3.05	.006	.071	2.21	.40	40.8	5.5	39.4	39.1	57.1
Do	689.5	2.82	......	.068	2.04	.35	37.7	......	37.8	36.1	50.0
Average	......	2.94	.006	.070	2.12	.38	39.2	5.5	38.6	37.6	53.5
Average of 6 tests in hot water	......	......	......	......	......	......	35.1	7.0	35.8	34.3	40.2

Even under the most favorable conditions the loss during the cooking of cabbage is very great, being 30 per cent of the total dry matter when distilled water is used and as high as 40 per cent when limewater is used. In the latter case over one-half of the mineral matter and over one third each of the carbohydrates and nitrogenous matter are dissolved out during the process of cooking. The albuminoid matter seems to be less soluble than any other of the substances present, there being but from 5 to 10 per cent of loss. Since albuminoids make up 61 per cent of the total nitrogenous substances, it follows that with a loss of from 35 to 40 per cent of the total nitrogenous matter nearly all of the nonalbuminoid nitrogenous compounds must be dissolved out in the water in which the cabbage is cooked. It will be noticed that the loss of albuminoid nitrogen was much greater where alkaline water was used than with either distilled or limewater. The average loss in the cooking of cabbage is shown graphically in fig. 6.

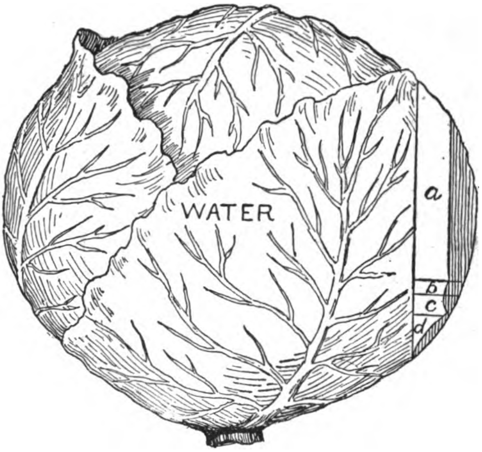


FIG. 6.—The composition of the cabbage and the loss of nutrients when boiled: *a*, starch, sugar, fiber, fat, etc.; *b*, nonalbuminoid nitrogenous matter; *c*, albuminoid nitrogenous matter; *d*, mineral matter. The hatched portion represents the loss.

CONCLUSIONS.

The kind of water used has more effect on the loss of nutrients in cooking cabbage than the temperature of the water at which the cooking is started. In any case the loss is large. In 100 pounds of uncooked cabbage there are but 7½ pounds of dry matter, and of this dry matter from 2¼ to 3 pounds are lost in the process of cooking. This loss seems to be unavoidable unless the cabbage is cooked in such a manner that the water in which it is boiled is also used. This is frequently the case when cabbage is cooked with corned beef.

GENERAL SUMMARY.

The losses which occur in cooking potatoes, carrots, and cabbage vary with the different methods of boiling followed, being quite considerable in some cases. These losses must be taken into account in computing dietaries and made good by adding other materials to supply the nutrients lost. While the loss is not so great as to render it imperative that people in comfortable circumstances should abandon methods of preparing these foods which they consider make them most palatable, there are very large numbers who can not afford to permit even the comparatively small waste of food observed in these experiments.

The purpose of experiments, such as those here reported, is to learn what actually takes place in the process of preparing food by the common methods. Those having charge of the preparation of food must determine how far it is desirable under individual circumstances to apply the information obtained.

THE DIGESTIBILITY OF POTATOES AND EGGS.

By H. SNYDER, B. S.,

Chemist, Minnesota Agricultural Experiment Station, and Professor of Agricultural Chemistry, College of Agriculture, University of Minnesota.

INTRODUCTION.

There seems to be a very wide difference of opinion regarding the digestibility of the potato, some considering it a very easily digested food and others a food digested with some difficulty. The information on which such opinions are based is comparatively limited. Our knowledge concerning the digestibility of food is quite largely based on artificial digestion experiments. The number of experiments made with man is comparatively small. An experiment with man on the digestibility of potatoes was made by Rubner and reported some years ago.[1]

More work of this nature seemed desirable, therefore an experiment was undertaken with a healthy man in which potatoes formed the principal article of diet. Potatoes being almost entirely a farinaceous food, it was necessary to have some easily digested albuminoids in the dietary and also some fat, since previous digestion experiments in this laboratory have indicated that in order to obtain normal digestion it is necessary to use a well-balanced ration supplying a sufficient amount of nitrogenous material for replenishing the waste tissues of the body. To furnish this nitrogenous matter and fat hard-boiled eggs were added. Upon trial the diet of potatoes and eggs proved an unnatural and distasteful one to the subject and it was found necessary to add some milk and a little cream to the dietary in order to make it well balanced and palatable.

The digestibility of the eggs was first determined by the Stutzer method of artificial digestion, to learn something of the effect of boiling for various periods. Such knowledge was considered essential in the interpretation of the results of the experiments with man. The digestibility of the milk and cream were assumed as described beyond.

DIGESTIBILITY OF BOILED EGGS IN PEPSIN SOLUTION.

Five experiments were made to determine the digestibility of eggs cooked under different conditions. A pepsin solution was prepared consisting of 1.1 parts of pepsin and 7.5 parts of hydrochloric acid in

---

[1] Ztschr. Biol., 1879, p. 147. U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 60.

500 parts of water. This solution dissolved 50 parts of hard-boiled egg albumen in six and one-half hours at a temperature of from 38° to 40° C.

Eggs were cooked for 3 minutes at 100° C., giving a "soft-boiled" egg, and for 5 minutes and 20 minutes at the same temperature. One egg boiled 3 minutes and digested for 5 hours in about 200 cc. of pepsin solution as prepared above, compared with one boiled 20 minutes and treated in the same way, showed 8.3 per cent undigested nitrogen in the former, against 4.1 per cent undigested nitrogen in the latter. Under similar treatment the egg boiled 5 minutes gave 3.9 per cent undigested nitrogen.

Another trial was then made, in which the eggs were cooked for periods of 5 and 10 minutes in water at 82.2° C. (180° F.) In both of these cases the nitrogen was entirely digested in 5 hours. The results are given in the following table:

Result of digesting boiled eggs 5 hours in pepsin solution.

No. of experiment.	Length of time cooked.	Temperature at which cooked.	Weight egg used (without shell).	Total nitrogen in fresh eggs.	Total undigested nitrogen.	Total nitrogen digested.	Pepsin solution used.
	Minutes.	*Deg. F.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Cc.*
1	5	180	39.34	.944	....	100.0	197
2	10	180	47.02	1.128	....	100.0	235
3	3	212	38.67	.929	0.0768	91.7	193
4	5	212	43.80	1.050	.0408	96.1	219
5	20	212	40.64	.960	.0408	95.8	203

From the above it seems probable that while the method of cooking has some effect upon the rate of digestibility it does not materially affect the total digestibility. These results agree quite closely with those obtained by Rubner.[1] In an experiment with man he found that 97.1 per cent of the nitrogen of hard-boiled eggs was digested.

DIGESTION EXPERIMENT ON MAN WITH A DIET OF POTATOES, EGGS, MILK, AND CREAM.

The subject of the digestion experiment was a healthy man, 22 years old. He was a laboratory assistant, and his work did not demand a great amount of muscular exercise. The experiment began with dinner May 14, 1896, and ended after dinner May 18, covering 13 meals, or 4⅓ days. The weight of the subject (without clothing) at the beginning of the experiment was 62.5 kilograms (137½ pounds) and at the end 62.6 kilograms (137¾ pounds).

The daily dietary as finally adopted consisted of 1587.6 grams (3½ pounds) of potatoes, 8 eggs, 710 cubic centimeters (1½ pints) of milk, and 237 cubic centimeters (½ pint) of cream. The latter was necessary in order to supply fat to raise the fuel value of the food to the desired point. The approximate amounts and the composition of each food consumed per day are shown in the following table:

---

[1] Ztschr. Biol., 1879, p. 128. U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 61.

Amount and composition of preliminary daily diet.

	Solid matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Potatoes (1,587 grams)	362.88	6.35	39.92	0.45	299.38	14.51	1,394
Eggs (8, hard boiled)	113.40	8.16	50.80	48.99	....	4.08	664
Milk (710 cubic centimeters)	90.72	4.08	25.40	27.22	30.39	4.98	482
Cream (237 cubic centimeters)	40.82	.91	5.44	34.02	3.63	1.36	355
Total	607.82	19.50	121.56	110.68	333.40	24.93	2,895

This diet was given for three days before the experiment began in order that the body might get into equilibrium with it.

After breakfast on the day the experiment commenced and after dinner on the day it closed some charcoal in gelatin capsules was taken, in order to identify the feces belonging to the food of the experiment proper. The fresh feces weighed on an average 204 grams per day and the urine 1,108 grams. The food, urine, and feces were analyzed. The composition of the total food eaten and of the total feces, together with the nutrients contained in the food eaten and lost in the feces and the percentage of each nutrient digested, are shown in the following tables:

Weight and composition of food eaten and of feces for four and one-third days.

	Weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per gram, calculated.
	Grams.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Potatoes	6,380	28.85	9.50	0.08	19.27	0.90	0.935
Eggs	1,800	23.86	12.63	11.23	....	.86	1.739
Milk	2,722	12.27	3.25	4.01	5.01	.75	.757
Cream	908	17.41	1.69	14.00	1.72	.60	1.465
Feces	*a* 206	82.33	26.56	14.30	*b* 41.47	16.27	4.490

a Water-free substance.
b One and four-tenths per cent is allowed for biliary products. Carbohydrates = 100.00 – (Protein + Fat + Ash + 1.40).

Weights and fuel values of nutrients in food eaten and in feces for four and one-third days; and weights, fuel value, and percentages of nutrients digested.

	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Potatoes	1,394.0	159.5	5.1	1,229.4	57.4	5,965
Eggs	429.5	227.4	202.1	....	16.5	3,130
Milk	334.0	88.5	109.1	136.4	20.4	2,060
Cream	158.0	15.3	127.1	15.6	5.4	1,330
Total eggs, milk, and cream	921.5	331.2	438.3	152.0	42.3	6,520
Total, from whole food	2,315.5	490.7	443.4	1,381.4	99.7	12,485
Fuel value of urea (435.9×0.87)	....	....	....	....	....	379
Net fuel value of food eaten	....	....	....	....	....	12,106
Feces, i. e., undigested residue	169.9	54.8	29.5	85.6	33.6	926
Amount digested in whole food	2,145.6	435.9	413.9	1,295.8	66.1	11,180
Amount eggs, milk, and cream digested	882.1	321.2	....	152.0	....	6,192
Amount potatoes digested	1,263.5	114.7	....	1,143.8	....	4,988
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Per cent digested of whole food	92.7	88.8	93.3	93.8	(*a*)	89.5
Per cent digested of potatoes	90.6	71.9	....	93.0	....	83.6

a An unknown amount of salt was eaten, which renders the amount of mineral matter digested somewhat doubtful.

In calculating the amount of nutrients furnished by the eggs, milk, and cream that were digested, it is assumed that 97 per cent of the protein and all of the carbohydrates (chiefly milk sugar) in these foods were digested. Inasmuch as the amount of fat in the potato is so extremely small, no attempt was made to calculate its digestibility. The figures for the digestibility of the whole food (93 per cent) practically represent the digestibility of the fat in the eggs, milk, and cream. The amount of nutrients digested in the eggs, milk, and cream deducted from the total digested nutrients gives the nutrients digested from the potato. The percentages digested were calculated from these amounts. In calculating the fuel value 1 gram of protein is assumed to yield 5.5 calories, 1 gram of fat 9.3 calories, and 1 gram of carbohydrates 4.1 calories. Nitrogenous matter is not as completely oxidized in the body as when burned in the air,[1] since it is largely excreted in the form of urea. Urea contains some energy, which is, however, unavailable to the body. Briefly, the fuel value of urea is calculated as follows:[2]

$$\frac{\text{M protein}}{6.25} \times 2.143 \times 2.53 = \text{fuel value of urea.}$$

This may be reduced to the simpler form, M protein × 0.87=fuel value of urea.

More or less salt was eaten of which no account was made, therefore the digestibility of the ash is not calculated. It is of comparatively little importance, since to some extent at least the soluble mineral matters, e. g., salt, pass directly to the kidneys, from which they may be secreted within a few hours after being taken into the stomach.

DISCUSSION OF RESULTS.

From the results of this experiment it would seem that while the nitrogenous matter is not very completely digested, the digestibility of the carbohydrates is quite high. Since the potato consists very largely of carbohydrates, it may be regarded, at least in the case of the person here experimented with, as a food which is well digested. The results obtained in this experiment agree very closely with those obtained by Rubner (see p. 21), as will be seen by the following comparison:

The digestibility of potatoes as determined by American and European investigators.

	Protein digested.	Carbohydrates digested.
	Per cent.	*Per cent.*
The author's experiment	71.9	93.0
Rubner's experiment	67.8	92.4

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 103.

[2] Connecticut Storrs Sta. Rpt. 1894, p. 125.

The nitrogen balance.—The urine was collected during the period covered by the digestion experiment, and the total of solids, nitrogen, and ash in it determined. In this way a balance of income and outgo of nitrogen could be obtained and the resultant gain or loss of protein calculated. The amount of urine excreted during the period covered by the experiment was 4,800 grams. It contained 6.18 per cent of water-free substance, 1.42 per cent of nitrogen, and 1.63 per cent of ash. The gain or loss of nitrogen and the calculated gain or loss of protein per day are shown in the following table:

Balance of income and outgo of nitrogen and gain of protein.

	Nitrogen in food.	Nitrogen in feces.	Nitrogen digested.	Nitrogen in urine.	Nitrogen gained.	Protein gained.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Quantities for whole period (4⅓ days)...	78.51	8.77	69.74	68.16	1.58	9.88
Quantities per day......................	18.14	2.03	16.11	15.74	.37	2.31

During the experiment the subject gained 9.88 grams (one-third of an ounce) of protein. Assuming that muscle contained 23 per cent of protein, the subject gained 43 grams of muscle, or about 1½ ounces.

THE COMPOSITION OF DIFFERENT PARTS OF THE POTATO AND THE LOSS OF NUTRIENTS DURING THE PROCESS OF BOILING.

By ALMAH J. FRISBY, M. D., and A. P. BRYANT, M. S.

INTRODUCTION.

The potato is composed of three parts, which may for convenience be termed outer skin, inner skin, and flesh. The outer or true skin is dry in appearance, usually grayish brown in color and corresponds to the bark of the rest of the plant. The portion lying immediately beneath the skin is slightly colored, containing whatever coloring matter may be present in the potato, and is the part which turns green on continued exposure to the sunlight, giving a strong unpleasant taste to the potato. This portion has some resemblance to the skin in general appearance, and is usually removed with the skin in preparing potatoes for the table. Its true name is the fibro-vascular layer, but it is also sometimes designated as the herbaceous or cortical layer, subcutaneous portion, and inner skin (see fig. 7). The main bulk of the potato is composed

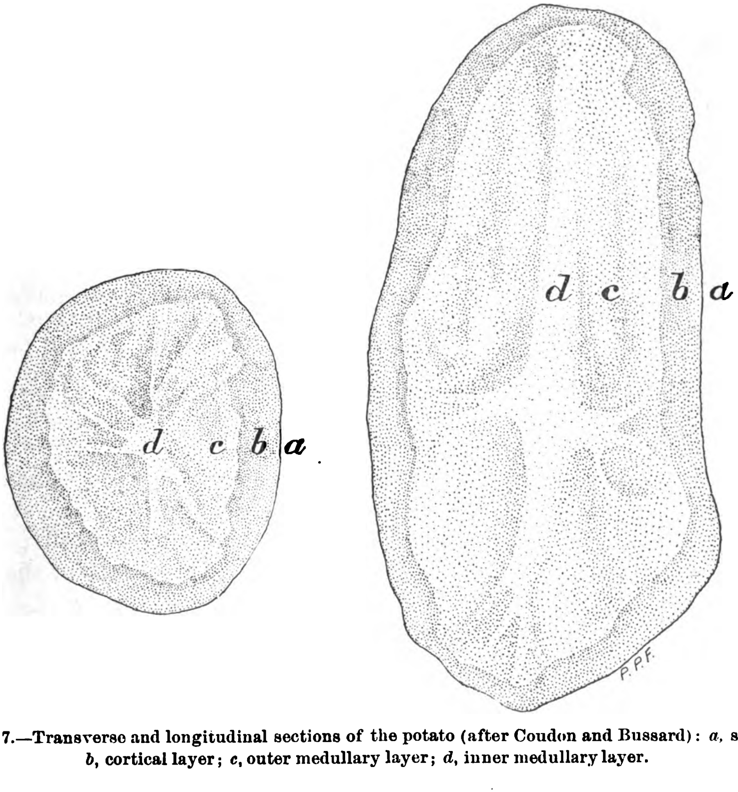


FIG. 7.—Transverse and longitudinal sections of the potato (after Coudon and Bussard): *a*, skin; *b*, cortical layer; *c*, outer medullary layer; *d*, inner medullary layer.

filled with starch grains and a little nitrogenous matter, and may be designated as the flesh of the potato.

[Shortly after the completion of the present bulletin an extended study of potatoes was reported by H. Coudon and L. Bussard.[1] The authors investigated the botanical structure of a large number of varieties of potatoes and determined the relative composition of large, medium, and small potatoes and of the different parts of the tubers. The taste and culinary properties of a number of standard varieties were also investigated. The potatoes were cooked in several ways. Among the conclusions reached by the authors were the following: In judging the value of a variety of potatoes analyses should be made of a number of entire tubers. The culinary value of the potato is directly proportional to its nitrogen content and inversely proportional to its starch content. The different varieties of potatoes were found to vary greatly in their resistance to boiling, some retaining their form completely, while others were almost entirely disintegrated. In the author's opinion the resistance to boiling did not depend upon the content of pectin or starch, but seemed to depend principally upon the relative proportion of albuminoids present. No definite relation was observed between chemical composition and early maturity. Generally speaking, the early varieties contained more water and nitrogenous material and less starch than the late varieties. The number of exceptions was, however, large.]

In order to ascertain to some extent the variation in composition of the different parts of the tuber a quantity of smooth potatoes of average size was obtained and analyses of the different parts made. The variety selected was that known as the "White Star."

COMPOSITION OF DIFFERENT PARTS OF THE POTATO.

SAMPLING.

Twelve medium-sized potatoes of known weight were taken. The skin was carefully removed by scraping with a knife and the skin and potatoes weighed. The sum of the weights of the scraped potatoes and of the skins did not equal the weight of the potatoes at the start. More or less water had evaporated from the moist surfaces. It was assumed that half of the loss came from the skins and half from the smooth surface of the scraped potatoes, inasmuch as the amount of surface freshly exposed to the air was the same in the two portions. The inner skin of the potatoes, or fibro-vascular layer, was next removed by scraping, care being taken to include as little flesh of the potato as possible. The amount removed by this operation was weighed as before and the loss of water during the process divided equally between the part removed and the part remaining, i. e., the flesh. The three portions were dried at 100° C. and this partially dried material of cells was analyzed. The weights of the different parts and their proportion of the whole potato were as follows:

---

[1] Ann. Sci. Agron., 1897, I, No. 2, p. 250.

Proportions of different parts of the potato.

	Weight in grams.	Per cent of whole.
Twelve unpeeled potatoes	1,633	100.0
Outer, or true, skin	41	2.5
Inner skin or fibro-vascular layer[a]	139	8.5
Flesh	1,453	89.0

[a] Including a small amount of flesh.

THE ANALYSES.

Water, nitrogen, fat, and ash were determined by the usual methods. Crude fiber was determined in the fibro-vascular layer and the flesh, but there was so little of the skin left after making the other determinations that the estimation of fiber could not be made. It would, however, presumably be quite high.

The nitrogen of the potato is not all in the form of true albuminoids or proteids, but nearly half is in the form of amido compounds, including, principally, asparagin.[1] Inasmuch as the amount of nitrogenous material in the potato is small, and the amido compounds can neither build tissue nor repair waste as do the albuminoids, the nutritive value of the nitrogenous substance (protein) of the potato is very small. In the experiments here reported the albuminoid nitrogen was determined by Stutzer's method.

The composition of different parts and the calculated composition of whole potatoes here analyzed as compared with results of other American and European analyses are shown in the following table:

Composition of the whole potato and its different parts.

	Water.	Nitrogen.		Protein.	Fat.	Carbohydrates.		Ash.
		Albuminoid.	Total.			Nitrogen-free extract.	Fiber.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Outer, or true, skin	80.1	0.25	0.43	2.7	0.8	14.6		1.8
Inner skin or fibro-vascular layer	83.2	.24	.36	2.3	.1	12.6	0.7	1.1
Flesh	81.1	.18	.32	2.0	.1	15.7	.3	.8
Calculated composition of whole potato	81.3	.19	.32	2.0	.1	15.7		.9
Average of 86 American analyses[a]	78.0	....	.35	2.2	.1	18.8		.9
Average of 178 European analyses[b]	75.0	.19	.34	2.1	.1	21.0	.7	1.1

[a] From an unpublished compilation of analyses of American food products.
[b] König, Chemie der Nahrungs- und Genussmittel, 3d ed., II, p. 626.

Although of fine appearance, the potatoes used in the present experiment contained an unusually small amount of dry matter and a large proportion of water, as will be seen by comparing their chemical composition with that of average potatoes. Whether this was due to the variety or to the year is a matter of doubt. The skin, although apparently very dry, contained nearly as large a percentage of water as the rest of the potato. The portion immediately under the true skin, i. e., the fibro-vascular layer, contained the greatest amount of water. Payen[1] states that the epidermis and the herbaceous portion immediately below it contain little or no starch deposit. The above results seem to be in accord with this, though no estimation of starch itself was made. It will be noticed that the skin contains about 40 per cent more albuminoid nitrogen than the flesh, and more than twice the amount of mineral matter (ash). One of the most noticeable differences is the relatively large amount of ether extract in the skin—nearly 1 per cent. This had much the appearance of wax, and had an odor slightly resembling that of beeswax.

---

[1] Schulze, Barbieri, and Eugster, Land. Vers. Stat., 21 (1878), p. 63; 27 (1882), p. 357. See also König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., II, p. 631.

THE PROTEIN FACTOR.

The protein was determined as usual by multiplying the total nitrogen by the factor 6.25. This factor is based on the assumption that there is on the average 16 per cent of nitrogen in protein. In the case of potatoes the results thus obtained are considerably too large. In the first place, the nonalbuminoid compounds have a much larger proportion of nitrogen than do the albuminoids, and consequently should be obtained by the use of a much smaller factor than 6.25. Besides this, the albuminoids themselves contain slightly more than 16 per cent of nitrogen. Osborne and Campbell[2] have investigated the proteid of the potato, which they propose to call "tuberin," and find that it contains 16.24 per cent of nitrogen.

For the present purpose it will be convenient to assume that all the nonalbuminoid nitrogen of the potato occurs in forms more or less similar to asparagin. Asparagin contains 21.21 per cent of nitrogen. The average amount of albuminoid nitrogen in potatoes is 56 per cent of the whole, which is the same proportion as was found in the flesh of the potatoes used in these experiments. Assuming 56 per cent of the nitrogen of the potato to belong to albuminoid nitrogenous matter (tuberin) and the remaining 44 per cent of the nitrogen to belong to nonalbuminoid nitrogenous matter (asparagin), there will be an average of 18.42 per cent of nitrogen in the nitrogenous substance of the potato. This corresponds to the factor 5.43.

In round numbers, therefore, 5.5 may be taken as the factor by which the total nitrogen of the potato should be multiplied in order to obtain the total nitrogenous matter or protein. While the change made by using this instead of the ordinary factor 6.25 for calculating the protein is slight, it would amount to about a gram of protein per day in the case of a person eating 340 grams ($\frac{3}{4}$ pound) of potatoes daily. The difference in composition as computed by using the factor 5.5 for calculating protein instead of the factor 6.25 is shown in the following table:

---

[1] Substances alimentaires, p. 305.

[2] Connecticut State Sta. Rpt. 1895, p. 255 (E. S. R., 8, p. 371).

Comparison of the composition of the potato when the factor 5.5 is used instead of the factor 6.25 in calculating protein.

	Water.	Protein.		Fat.	Carbohydrates by difference.*a*		Ash.
		Nitrogen × 5.5.	Nitrogen × 6.25.		When protein = N × 5.5.	When protein = N × 6.25.	
	Per ct.	*Per cent.*	*Per cent.*	*Per ct.*	*Per cent.*	*Per cent.*	*Per ct.*
Outer, or true, skin	80.1	2.4	2.7	0.8	14.9	14.6	1.8
Inner skin or fibro-vascular layer	83.2	2.0	2.3	.1	13.6	13.3	1.1
Flesh	81.1	1.8	2.0	.1	16.2	16.0	.8
Calculated composition of whole potato	81.3	1.8	2.0	.1	15.9	15.7	.9
Average of 86 American analyses	78.0	1.9	2.2	.1	19.1	18.8	.9

a 100 less the sum of the percentages of water, protein, fat, and ash.

AMOUNT OF SOLID MATTER IN THE JUICE OF THE POTATO.

When we consider the amount of water in the potato, it is to be expected that a considerable portion of the ingredients may be in solution. If a potato be grated and the juice pressed through a linen cloth a large amount of dark-colored liquid is obtained having an acid character. This acidity is commonly said to be chiefly due to citric acid with more or less tartaric and succinic acids. The mineral water is very largely in the form of potash salts, soluble in water. The asparagin present is also soluble in water, and the tuberin more or less soluble in the acid. The following table shows the percentages of the different substances found in the juice of the potato and in the solid matter:

Distribution of material in the solid matter and juice of the potato. a

	Dry matter.	Nitrogen.			Ash.
		Albuminoid.	Nonalbuminoid.	Albuminoid + nonalbuminoid.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
In solid matter	85	15	0	15	15
In juice	15	49	36	85	85
Total	100	64	36	100	100

a Lawes and Gilbert, On the Growth of the Potato, p. 26, Rothamsted Memoirs, vol. 6.

LOSS OF NUTRIENTS IN BOILING.

Since 85 per cent of the nitrogenous matter and 85 per cent of the mineral matter are in a state of solution in the potato, it would seem quite probable that there might be a considerable loss of these substances during the process of preparing potatoes for the table. Experiments were therefore made to investigate this loss and determine its amount. Four trials were made, (1) with the skins removed, the peeled potatoes being put in cold water, which was heated at once over a moderate flame; (2) with the skins removed, the peeled potatoes placed directly in boiling water; (3) with the skins on, the potatoes being put in cold water, which was heated as in the first case; and (4) with the skins on, the potatoes being placed directly in hot water as in the second case. Six medium-sized potatoes were used for each trial. They were boiled in one liter of distilled water in an aluminum kettle until they were easily pierced with a fork. The kettle was then removed from the fire, the water poured off, and the potatoes rinsed with distilled water. It was found that the potatoes in every case except the second gained slightly in weight during the process of cooking. This gain was evidently due to water absorbed.

The water in which the potatoes were boiled, united with that used in rinsing them after boiling, was made up to a definite volume by adding distilled water. Aliquot portions were taken for analysis. The cooked potatoes were also dried and analyzed. In most cases the amount of each substance found by analysis in the water used in cooking them, added to the amount of the same substance found in the cooked potatoes, gave, within the limits of analytical error, the total amount of that substance calculated as being present in the raw potatoes. The weight of any substance found in the water used in cooking the potatoes divided by the weight of that same substance calculated as being present in the uncooked potatoes gave the percentage of loss during boiling. The loss of carbohydrates was estimated by subtracting the sum of the protein lost (calculated by multiplying the total nitrogen lost by 5.5) and the mineral matter lost from the total loss of dry matter.

The following table gives the loss of nutrients when the potatoes were cooked in different ways:

The loss of material during the process of cooking potatoes.

	Dry matter.	Nitrogen.			Carbohydrates.	Ash.
		Albuminoid.	Nonalbuminoid.	Total.		
Skins removed before boiling.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water cold at beginning of test	3.7	4.3	12.9	8.3	2.5	17.0
Water hot at beginning of test	4.0	3.3	17.9	10.0	2.8	17.4
Average	3.9	3.8	15.4	9.2	2.7	17.2
Boiled with skins on.						
Water cold at beginning of test	.3	.6	.6	.6	.2	1.9
Water hot at beginning of test	.3	.4	1.7	1.0	.1	1.2
Average	.3	.5	1.1	.8	.2	1.6

It will be seen that the loss of matter during the process of cooking was confined quite largely to the nitrogenous substances and the mineral matter. The total loss of dry matter, however, was in some cases considerable, indicating a loss of starch and other carbohydrates. The loss of nitrogen and mineral matter is easily explained by supposing that substances which were dissolved in the juices simply passed out into the water. The loss of the carbohydrates, on the other hand, is probably largely mechanical.

It will be noticed that the calculated loss of carbohydrates was almost nothing when the potatoes were protected by their skins. When the skins were removed before cooking, more or less of the softened and broken cell walls and swollen starch grains were abraded during the process of boiling. Although this process is mechanical, the material removed is just as truly lost as if an equivalent amount of starch had been converted into dextrin during the boiling and then dissolved. Possibly there is a slight loss of starch which is chemical rather than mechanical. In roots, such as beets, turnips, and carrots, there is more or less sugar which might dissolve out, but the fresh potato contains practically no sugar.

CONCLUSIONS.

When potatoes are boiled with the skins removed, there is a very considerable loss not only of organic nutrients but also of mineral salts. These salts, while not nutrients in the sense in which this term is frequently used, are nevertheless important in nutrition. They are of especial value, because of the potassium compounds which they contain, and are apparently necessary for health.

The greatest actual loss of nutrients seems to be due to the mechanical abrasion of the soft outer portions of the potato while cooking. In this case nearly 3 per cent of the carbohydrates and 4 per cent of the available flesh-forming nitrogenous matter are lost. When the potatoes are boiled with their skins on, the loss of nutrients is very slight, consisting chiefly of nonalbuminoid nitrogenous substances and mineral matter. It is self-evident that if it is desired to boil potatoes with as little loss as possible the skins should be left on.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN.[1]

Charts. Food and Diet. By W. O. Atwater. (Four charts, 26 by 40 inches.) Price per set, unmounted, 75 cents; mounted, $1.

Bul. 21. Methods and Results of Investigations on the Chemistry and Economy of Food. By W. O. Atwater. Pp. 222. Price, 15 cents.

Bul. 28 (Revised edition). The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant. Pp. 87. Price, 5 cents.

Bul. 29. Dietary Studies at the University of Tennessee in 1895. By C. E. Wait, with comments by W. O. Atwater and C. D. Woods. Pp. 45. Price, 5 cents.

Bul. 31. Dietary Studies at the University of Missouri in 1895, and Data Relating to Bread and Meat Consumption in Missouri. By H. B. Gibson, S. Calvert, and D. W. May, with comments by W. O. Atwater and C. D. Woods. Pp. 24. Price, 5 cents.

Bul. 32. Dietary Studies at Purdue University, Lafayette, Ind., in 1895. By W. E. Stone, with comments by W. O. Atwater and C. D. Woods. Pp. 28. Price, 5 cents.

Bul. 35. Food and Nutrition Investigations in New Jersey in 1895 and 1896. By E. B. Voorhees. Pp. 40. Price, 5 cents.

Bul. 37. Dietary Studies at the Maine State College in 1895. By W. H. Jordan. Pp. 57. Price, 5 cents.

Bul. 38. Dietary Studies with Reference to the Food of the Negro in Alabama in 1895 and 1896. Conducted with the Cooperation of the Tuskegee Normal and Industrial Institute and the Agricultural and Mechanical College of Alabama. Reported by W. O. Atwater and C. D. Woods. Pp. 69. Price, 5 cents.

Bul. 40. Dietary Studies in New Mexico in 1895. By A. Goss. Pp. 23. Price, 5 cents.

Bul. 43. Losses in Boiling Vegetables and the Composition and Digestibility of Potatoes and Eggs. By H. Snyder, A. J. Frisby, and A. P. Bryant. Pp. 31. Price, 5 cents.

Bul. 44. Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism with a Respiration Calorimeter of Special Construction. By W. O. Atwater, C. D. Woods, and F. G. Benedict. Pp. 64. Price, 5 cents.

Bul. 45. A Digest of Metabolism Experiments in which the Balance of Income and Outgo was Determined. By W. O. Atwater and C. F. Langworthy. Pp. 434. Price, 25 cents.

Bul. 46. Dietary Studies in New York City in 1895 and 1896. By W. O. Atwater and C. D. Woods. Pp. 117. Price, 10 cents.

Bul. 52. Nutrition Investigations in Pittsburg, Pa., 1894–1896. By Isabel Bevier. Pp. 48. Price, 5 cents.

Bul. 53. Nutrition Investigations at the University of Tennessee in 1896 and 1897. By C. E. Wait. Pp. 46. Price, 5 cents.

Bul. 54. Nutrition Investigations in New Mexico in 1897. By A. Goss. Pp. 20. Price, 5 cents.

Bul. 55. Dietary Studies in Chicago in 1895 and 1896. Conducted with the Cooperation of Jane Addams and Caroline L. Hunt, of Hull House. Reported by W. O. Atwater and A. P. Bryant. Pp. 76. Price, 5 cents.

Bul. 56. History and Present Status of Cooking in the Public Schools of New York City. Reported by Mrs. Louise E. Hogan, with an introduction by A. C. True, Ph. D. Pp. 70. Price, 10 cents.

Bul. 63. Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body. By W. O. Atwater and E. B. Rosa. Pp. 94. Price, 10 cents.

Bul. 66. The Physiological Effect of Creatin and Creatinin and their Value as Nutrients. By J. W. Mallet. Pp. 24. Price, 5 cents.

FARMERS' BULLETINS.

Bul. 23. Foods: Nutritive Value and Cost. By W. O. Atwater. Pp. 32.
Bul. 34. Meats: Composition and Cooking. By C. D. Woods. Pp. 29.
Bul. 74. Milk as Food. Pp. 39.
Bul. 85. Fish as Food. By C. F. Langworthy. Pp. 30.
Bul. 93. Sugar as Food. By Mary Hinman Abel. Pp. 27.

---

[1] For those publications to which a price is affixed, application should be made to the Superintendent of Documents, Union Building, Washington, D. C., the officer designated by law to sell Government publications.

BULLETIN NO. 67.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS.
A. C. TRUE, Director.

STUDIES
ON
BREAD AND BREAD MAKING.

BY

HARRY SNYDER, B. S., and L. A. VOORHEES, M. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1899.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 17, 1899.

Sir: I have the honor to transmit herewith a report of investigations on bread and bread making at the University of Minnesota in 1897 and 1898, by Prof. Harry Snyder, B. S., of the College of Agriculture of the University of Minnesota, and on losses in the process of making bread, by L. A. Voorhees, M. A., chief chemist of the New Jersey State Agricultural Experiment Station.

These investigations form a part of the nutrition investigations in charge of this Office, and were conducted under the supervision of Prof. W. O. Atwater, special agent in charge, in accordance with instructions given by the Director of this Office.

The investigations herewith reported belong to a series of inquiries into the nutritive value, digestibility, and economy of cereals, cereal products, and foods prepared from them. The effects of cooking are also taken into account. Progress reports of some of these studies have already been made, and the articles herewith submitted are of the same nature. On some points the results and conclusions are necessarily tentative and may be more or less modified by further investigations now in progress.

The reports are transmitted with the recommendation that they be published as Bulletin 67 of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page

Studies on bread and bread making at the University of Minnesota in 1897 and 1898. By Harry Snyder, B. S. 7
  Introduction 7
  Composition of samples of Minnesota bread and flour as related to their cost. 7
    Description of samples of bread and flour 8
    Composition of bread and flour 9
    Summary 10
  Loss of dry matter in bread making 11
  Loss of carbon as carbon dioxid 12
  Loss of carbon in the form of alcohol 15
  Loss of carbon as other volatile compounds 16
  Production of soluble carbohydrates in bread making 17
  Production of acids in bread making 19
  Behavior of the proteids of wheat flour in bread making 21
  Loss of nitrogen in bread making 27
  Changes in the solubility of fat during bread making 32
  Summary 33
  Digestibility of bread 34
Losses in the process of making bread. By L. A. Voorhees, M. A. 37
  Introduction 37
  Loss of material in bread making 41
    Experiments in 1898—Methods followed 41
    Effect of heat on milk 42
    Tests with bread made in various ways 42
    Tests with flour from which the gliadin was extracted 45
    Comparison of different methods of extracting fat 46
    Comparison of experimental methods 48
  Conclusions 50

ILLUSTRATIONS.

Page.
PLATE I. Appearance of starch grains in bread 19
II. Bread from normal flour, from mixtures of normal and extracted flour, and from mixtures of normal and corn flour 23
FIG. 1. Apparatus for determining carbon dioxid evolved during baking of bread 12
2. Apparatus for determining carbon dioxid evolved during fermentation of bread 13
3. Gluten from two samples of flour 22

STUDIES ON BREAD AND BREAD MAKING.

STUDIES ON BREAD AND BREAD MAKING AT THE UNIVERSITY OF MINNESOTA IN 1897 AND 1898.

By Harry Snyder, B. S.,
Chemist, Agricultural Experiment Station, and Professor of Chemistry, College of Agriculture, University of Minnesota.

INTRODUCTION.

The investigations which are reported in this bulletin have extended over two years, 1897 and 1898. The general purpose has been to study (1) the effect on the flour of the processes employed in bread making, that is, the action of ferments and heat, and the importance of these changes in household economy and in the manufacture of bread on a large scale; (2) the digestibility of bread from different sorts of flour, and (3) in connection with this work to study the chemical composition as related to the cost of bread and flour for sale in Minneapolis.

COMPOSITION OF SAMPLES OF MINNESOTA BREAD AND FLOUR AS RELATED TO THEIR COST.

The studies of the composition of bread were similar to those made at New Brunswick, N. J.,[1] and Pittsburg, Pa.[2] An extended study of the composition and cost of bread, biscuits or crackers, rolls, cakes, macaroni, and similar products for sale in Washington, D. C., has recently been reported by the Division of Chemistry of this Department in connection with an extended study of cereals and cereal products.[3]

In the investigations carried on at the Minnesota College of Agriculture a number of samples of bread and flour were purchased in Minnesota in the open market and analyzed. In several cases bread was made at the college. The usual analytical methods were followed.[4] The cost of the bread and flour was recorded when possible, with a view to learning whether the cost of bread was in proportion to the cost of the ingredients from which it was made. The further object was to see whether the various sorts of bread differed materially in composition, and to learn whether Minnesota bread was, generally speaking, the same in composition and cost as that for sale in other parts of the United States. A description of the samples analyzed at the Minnesota Station follows:

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 52.

[3] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1319.

[4] U. S. Dept. Agr., Division of Chemistry Bul. 46.

DESCRIPTION OF SAMPLES OF BREAD AND FLOUR.

No. 1. Baker's white bread of average quality.
2. White bread, "homemade." Made at the Minnesota Agricultural College kitchen from second-grade or baker's flour.
3. White bread, "homemade." Made at the Minnesota Agricultural College kitchen from first-grade or patent flour.
4. Graham bread, "homemade." Made at the Minnesota Agricultural College kitchen. This bread was not made from pure graham, but from a mixed flour.
5. Corn bread, "homemade," from the Minnesota Agricultural College kitchen. This was made of yellow Indian corn meal.
6. Graham bread from bakery. An average loaf of so-called graham bread. It was, however, made from an imitation of graham flour.
7. Rye bread from a bakery. This was an average rye bread.
8. White bread from bakery. An average bread made from roller-process flour.
9. Whole-wheat bread. This was made from genuine whole-wheat flour, a considerable amount of sugar being used.
10. Whole-wheat bread. This was made from the same flour as No. 9, but no sugar was used.
11. White bread from "first clearings," ground by the Washburn and Crosby Milling Company.
12. White bread from first patent flour made by Washburn and Crosby Milling Company.
13. Whole-wheat bread. This is an ordinary baker's whole-wheat bread.
14. Rye bread, "homemade."
15. Bread from "Roman" flour (whole wheat), "homemade."
16. Graham bread from the Minnesota Agricultural College kitchen. This was made from a so-called graham flour of unknown quality.
17. Corn bread. This was made at the Minnesota Agricultural College kitchen from white corn meal.
18. White bread, "homemade." This was made at the Minnesota Agricultural College kitchen from "Pillsbury's Best" flour.
19. Biscuit. These were made at the Minnesota Agricultural College kitchen.
20. White bread from high-grade patent, Consolidated Milling Company's flour. This is a type of very white bread.
21. White bread from regular patent, Consolidated Milling Company's flour.
22. Bread from first baker's flour from Consolidated Milling Company. This was a lower grade flour than that used in sample No. 21.
23. Bread made from low-grade flour. This was a lower grade flour than that used in sample No. 22 and known commercially as "Red Dog grade."
24. White bread, "homemade," from Cottage Grove. This was made from first-grade patent flour and was a good type of homemade bread.
25. Graham bread from Cottage Grove, "homemade."
26. Baker's white bread, "homemade" grade. An ordinary baker's bread as sold in market.
27. White bread, cheapest grade.
28. Baker's whole-wheat bread. This was evidently not a genuine whole-wheat bread.

29. Homemade bread. This was made from first-grade patent flour. The dough was mixed with water and no fat was added.
30. "Pillsbury's Best" flour.
31. Bread made from sample No. 30 ("Pillsbury's Best" flour).
32. Graham flour. This was known to be a true graham flour.
33. Bread, "homemade," from No. 32 (graham flour).
34. White patent flour.
35. Bread made from No. 34 (white flour).
36. White bread, "homemade," from whitest grade of flour.

COMPOSITION OF BREAD AND FLOUR.

The composition of the different samples of bread and flour is given in the table below. When the bread was purchased at a bakery the cost is included. In the case of homemade bread, where possible the cost of the bread was estimated. The weight of a loaf is also given. The table includes also the average composition of the different sorts of bread analyzed at the Minnesota Station, at New Brunswick, Pittsburg, and Washington.

Composition and cost of bread and flour.

Reference number.	Description of food material.	Price of loaf.	Weight of loaf.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
		Cents.	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Bakers' white bread	5	480	34.20	9.875	1.49	53.77	0.665
2	White bread, "homemade," from bakers' flour	1½	453$\frac{6}{10}$	32.80	10.437	.74	55.37	.654
3	White bread, "homemade" grade	1¾	453$\frac{6}{10}$	30.00	9.125	3.05	56.988	.837
4	"Graham bread" from flour which was not a true graham	2¼	453$\frac{6}{10}$	35.10	8.370	1.66	53.77	1.10
5	Corn bread, "homemade," from yellow Indian corn meal	1	453$\frac{6}{10}$	35.80	7.187	5.66	50.313	1.04
6	Bakers' graham bread	5	478	32.50	8.875	2.48	55.344	.801
7	Bakers' rye bread	5	471	36.70	8.187	.506	54.017	.59
8	Bakers' white bread, patent roller-process flour	5	482	33.40	9.781	2.14	54.101	.578
9	Whole-wheat bread made with sugar	1¾	453$\frac{6}{10}$	33.90	11.062	.473	53.621	.944
10	Whole-wheat bread made without sugar	1¾	453$\frac{6}{10}$	34.20	11.25	.56	53.075	.915
11	White bread made from first "clearing"	......	491	33.90	10.937	1.27	53.055	.838
12	White bread from first patent flour	......	488	32.70	9.785	.63	56.265	.620
13	Bakers' whole-wheat bread	5	495	32.30	11.687	.652	54.423	.938
14	Rye bread, "homemade"	2¼	453$\frac{6}{10}$	38.20	9.187	1.09	50.523	1.00
15	Bread from "Roman flour," "homemade"	3	453$\frac{6}{10}$	40.50	10.25	.898	47.572	.78
16	Graham bread, Minnesota College of Agriculture, "homemade"	2¼	453$\frac{6}{10}$	31.70	10.25	3.78	53.17	1.10
17	Corn bread made from white corn meal	1	453$\frac{6}{10}$	48.00	6.531	2.88	41.819	.77
18	White bread, "homemade," from "Pillsbury's Best" flour	1¾	453$\frac{6}{10}$	31.20	9.687	2.41	56.243	.46
19	Biscuit, Minnesota College of Agriculture, "homemade"	1¾	453$\frac{6}{10}$	30.70	10.219	1.95	56.601	.53
20	White bread from high-grade patent flour	......	492	32.90	8.75	1.37	56.47	.51
21	White bread from regular patent flour	......	496	34.10	9.03	1.28	54.91	.68
22	Bread from bakers' flour	......	492	39.10	10.645	1.21	48.205	.84
23	Bread from "Red Dog" grade of flour	......	490	40.70	12.593	1.14	44.277	1.29
24	White bread, "homemade"	1⅞	453$\frac{6}{10}$	27.70	9.438	.503	61.459	.90
25	Graham bread, "homemade"	2⅛	453$\frac{6}{10}$	27.80	10.687	1.44	58.923	1.15
26	Baker's bread, "homemade" grade	2½	484	28.40	8.72	1.95	60.38	.55
27	Baker's white bread, cheapest grade	2½	488	31.65	9.25	2.07	56.327	.703
28	Baker's whole-wheat bread, not a genuine whole-wheat bread	5	492	35.50	8.06	.578	54.868	.994
29	"Homemade" bread from first-grade patent flour, made with water, but no fat	1¾	453$\frac{6}{10}$	33.716	9.375	.660	55.667	.582
30	"Pillsbury's Best" flour	......	....	10.853	13.062	1.327	74.33	.428
31	"Homemade" bread from "Pillsbury's Best" (30)	1¾	453$\frac{6}{10}$	36.70	10.125	.758	51.969	.448
32	Graham flour, known to be a pure sample	2½	453$\frac{6}{10}$	10.825	14.812	2.988	69.897	1.478
33	"Homemade" bread from sample No. 32	......	....	34.244	9.375	3.251	51.854	1.276

Composition and cost of bread and flour—Continued.

Reference number.	Description of food material.	Price of loaf.	Weight of loaf.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
		Cents.	*Grams.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
34	White patent flour	(1)	....	12.362	12.437	1.62	73.075	.506
35	White bread made from sample No. 34	......	....	32.80	8.875	3.529	54.175	.621
36	"Homemade" white bread from whitest grade of flour	2	453$\frac{6}{10}$	34.13	8.937	1.089	55.193	.651
	Bread made from patent and baker's grades of flour (average of 17 Minnesota samples)	......	....	32.90	9.57	1.28	55.44	.81
	Bread made from graham and whole-wheat flours of known purity (average of 6 Minnesota samples)	......	....	33.82	10.55	1.21	53.41	1.01
	Bread made from imitation whole-wheat flour (average of 2 Minnesota samples)	......	....	33.10	9.16	2.64	54.06	1.04
	Corn bread (average of 2 Minnesota samples)	......	....	41.90	6.86	4.27	46.07	.90
	Rye bread (average of 2 Minnesota samples)	......	....	37.40	8.69	.80	52.31	.80
	Average of 77 samples of bread analyzed at New Brunswick[2]	......	....	35.81	9.30	1.26	52.55	1.08
	Average of 10 samples of bread analyzed at Pittsburg[3]	......	....	32.6	10.8	.5	54.8	1.3
	Vienna bread, average of 10 samples analyzed at Washington[4]	......	....	38.71	8.87	1.06	50.17	1.19
	"Homemade" bread, average of 2 samples analyzed at Washington[4]	......	....	33.02	7.94	1.95	56.04	1.05
	Graham bread, average of 9 samples analyzed at Washington[4]	......	....	34.80	8.93	2.03	51.65	1.59
	Rye bread, average of 7 samples analyzed at Washington[4]	......	....	33.42	8.63	.66	55.45	1.84
	Quaker bread, average of 3 samples analyzed at Washington[4]	......	....	36.16	7.78	1.14	53.86	1.06
	Miscellaneous bread, average of 9 samples analyzed at Washington[4]	......	....	34.41	7.60	1.48	55.02	1.49

---

[1] $4 per barrel.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 35, p. 10.

[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 52, p. 44.

[4] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1319.

SUMMARY.

The following general deductions were drawn from an examination of the different samples of Minnesota bread:

(1) Seventeen samples of Minnesota bread made from the patent and bakers' grades of flour gave an average of 9.57 per cent protein, the maximum and minimum amounts being 10.93 and 8.72, respectively.

(2) The high percentage of fat in some of the bread samples is caused by the large amounts of lard and other fats used for shortening purposes. From some of the samples of bread appreciably less fat was obtained in the dry matter than was present in the dry matter of the flour from which the bread was made. This apparent loss of fat is considered in another article in this bulletin (p. 37).

(3) The bread made from the imitation whole-wheat flours contained less protein than bread made from the patent and bakers' grades of flour, while the bread made from true whole-wheat flours—that is, flours from which none of the germ or other parts of the wheat had been removed—contained about 1 per cent more protein than bread made from ordinary flour. No conclusions, however, as to the relative nutri-

tive value of whole wheat and ordinary flours can be drawn from the figures given.

(4) The rye bread contained slightly less protein than ordinary wheat bread, while the corn bread contained less than the rye.

(5) The average "pound loaf" of fresh bread as sold by bakers weighed on an average about 480 grams, equivalent to about 1 pound 1 ounce.

(6) A pound loaf of bread can be made from about three-quarters of a pound of flour, about 25 per cent of water being added to the flour during the process of bread making. With some flours 5 to 10 per cent more water can be absorbed, making a greater weight of bread product from a given weight of flour. This additional weight is water and not nutrients. At 2 cents per pound for flour, it is estimated that a pound loaf of bread can be made, not counting fuel and labor, for about 2 cents, a half cent being allowed for shortening and yeast.

LOSS OF DRY MATTER IN BREAD MAKING.

In bread making the action of the yeast and heat results in: (1) The fermentation of the carbohydrates and the production of carbon dioxid and alcohol; (2) the production of soluble carbohydrates, as dextrin, from insoluble forms, as starch; (3) the production of lactic and other acids; (4) the formation of other volatile carbon compounds; (5) a change in the solubility of the proteid compounds; (6) the formation of amid and ammonium compounds from soluble proteids, and (7) the partial oxidation of the fat. In addition to these changes there are undoubtedly many others which take place. Inasmuch as many of the compounds formed during the fermentation process are either gases or are volatile at the temperature of baking, appreciable losses of dry matter must necessarily take place in bread making. These losses are usually considered as amounting to about 2 per cent of the flour used.[1] In exceptional cases, as in prolonged fermentation, under favorable conditions the losses may amount to 8 per cent or more.[2]

The losses, as determined by various investigators, are as follows: Voorhees,[3] 4.3 per cent; Heeren,[4] 1.57 per cent; Fehling,[4] 4.21 per cent; Graeger,[4] 2.14 per cent; Jago,[5] 2.5 per cent; Dauglish,[6] 3 to 6 per cent. The loss of dry matter in bread making is such an important matter, inasmuch as it has direct bearing upon the food value of bread, that it was deemed advisable to make a study of the subject in order to determine the exact nature and extent of the losses.

---

[1] U. S. Dept. Agr., Farmers' Bul. 23.

[2] Minnesota Sta. Bul. 54, p. 48.

[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[4] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 614.

[5] Jago, The Science and Art of Bread Making, p. 361.

[6] Ibid.

LOSS OF CARBON AS CARBON DIOXID.

A number of preliminary experiments were made in order to determine the best way of collecting the gas given off during the fermentation and baking processes. A baking tin was finally used, constructed in such a way that all the carbon-dioxid gas given off during the entire process could be collected and determined. The carbon dioxid was removed from all of the air admitted to the baking tin during both the rising and baking operations. A slow current of air was drawn through the baking tin, and all carbon dioxid produced by the action of the yeast and given off during the bread making was removed from the air that came from the baking tin. All of the flour, yeast, and water used in the several bakings were weighed, and all of the carbon dioxid produced in each operation was also collected and weighed.

Description of apparatus.—The baking tin *d* was provided with a tight-fitting cover, which was cemented to the pan with plaster-of-Paris cement.[1] The baking tin was connected with two block-tin pipes. Through pipe *c* air was admitted. The air before being admitted into the baking tin first passed through the wash bottles *a* and *b*, containing, respectively, potassium hydrate and soda-lime, materials used to absorb the carbon dioxid of the air. The air admitted into the baking tin through pipe *c* escaped through pipe *e*, which was connected with a glass condenser. The carbon dioxid given off during the process was carried with the air which was aspirated through *e*. In addition to air and carbon dioxid, alcohol and all other volatile products formed during the fermentation and baking operations were given off through *e*. The condenser was connected with an Erlenmeyer flask *g*, which received the alcohol, water, and condensed products. From the flask *g* the carbon dioxid passed through a wash bottle *h* and a tube *i*, both containing calcium chlorid, to remove the last traces of moisture

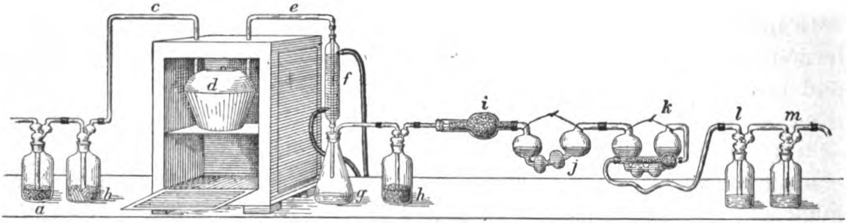


FIG. 1.—Apparatus for determining carbon dioxid evolved during baking of bread.

---

[1] This was selected as the most convenient means of cementing the cover to the bread pan. It is known that carbon dioxid will pass through plaster of Paris. It is believed, however, that in these experiments no material amount was lost in this way. The cover fitted the bread pan so closely that there was very little space between them; furthermore, the plaster of Paris was quite thick in proportion to its width, and no gas was allowed to accumulate in the tin or to exert any pressure upon the cement.

before the gas passed on into the absorption tubes *j* and *k*, where the carbon dioxid combined with potassium hydrate and was retained. The tubes *j* and *k* were of large size, each capable of absorbing 10 grams of carbon dioxid. The tubes were weighed before and after each operation. The increase in weight showed the amount of carbon dioxid absorbed. The potash bulb *k* was connected with wash bottles *l* and *m*, containing limewater, which was used to determine whether all of the carbon dioxid given off was absorbed by the potash bulbs. The tube passing out of *m* was connected with a suction pump. A current of air was drawn through the apparatus at the rate of about three bubbles per second. The apparatus used in the bread-making experiments was tested in the following way: Between wash bottle *b* and baking tin *d* a small carbon-dioxid generating flask was placed, containing 0.4025 gram of calcium carbonate, which gave by analysis 43.1 per cent CO_2, and 0.1715 gram of carbon dioxid was recovered from that generated in the baking apparatus from the calcium carbonate used. The theoretical amount called for was 0.1735 gram, the amount recovered being 98.8 per cent of the amount taken.

The apparatus used during the rising process was somewhat simplified (fig. 2). The tube *e* connected directly with an absorption tube *f* containing calcium chlorid, and only one potash bulb *g* was used.

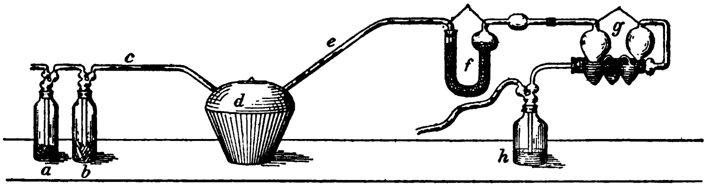


FIG. 2.—Apparatus for determining carbon dioxid evolved during fermentation of bread.

Before kneading the bread all the air in the baking tin was drawn off; the cover was then removed, and the bread was kneaded down gently. The cover was replaced and the liberated carbon dioxid was removed by drawing a current of air through the tin. The carbon dioxid being a heavy gas, it is assumed that it remained in the tin when the cover was temporarily removed. After the first gentle kneading and the removal of the liberated gas, the cover was removed and the bread was kneaded down without removing from the tin. The bread produced in this way was a little darker in color and was coarser grained than that made in the ordinary way.

In all, eight experiments were made. In the preliminary work flour from both spring wheat and winter wheat was used. As there seemed to be but little difference in the losses from either kind of flour, it was thought best to confine the work to one grade of flour, so that the results would be more comparable. (The patent roller-process spring-wheat flour used contained a much higher percentage of gliadin than the flour (No. 32) used in the bread experiment carried on in 1897 (see p. 22).

The flour used had the following composition:

Composition of the patent roller-process spring-wheat flour used.

	Per cent.
Water	11.86
Protein (N × 5.7)	11.96
Fat	1.33
Soluble carbohydrates	1.58
Starch[1]	67.22
Ash	.41
Undetermined	5.64

In four of the trials the bread was made by the short-fermentation process, while in four other trials the long-fermentation process was used. These methods are as follows:

Short-fermentation method.—A stiff dough is made of the flour, water, and yeast. It is thoroughly kneaded and is then allowed to rise until it doubles its bulk, when it is again kneaded thoroughly. After rising a second time it is baked. In the short-fermentation process a large quantity of yeast is used, and the time of fermentation is only about two and a half hours. The baking is completed in about four or four and one-eighth hours after the bread is first started to rise.

Prolonged fermentation.—A batter is made of the flour, yeast, and water, which is allowed to ferment ten or fifteen hours, usually over night. More flour is then added, the dough is kneaded until smooth, and then allowed to rise, and treated in the same way as in the first method. In the prolonged fermentation method less yeast is used than in the short process, and the fermentation is carried on for a longer time. In the prolonged fermentation trials the temperature during the first four or five hours was about 70° F. During the night the temperature of the room for four or five hours was about 50° F. In the trials reported in 1897[2] the temperature during the entire process was kept at a little over 70° F.

In the experiments reported no milk or fat was used in making the bread. The dough was made from a weighed quantity (about 400 grams) of flour. After kneading the dough, the amount of flour unused was deducted from the original amount. This gave the amount actually used for the bread. During baking the gas was given off rapidly at first, and then more slowly toward the close of the operation. The water and alcohol were given off almost entirely at the close of the operation. On account of the necessarily peculiar structure of the baking tin it was impossible to remove the bread without cutting it into small pieces. Hence the weight of the bread produced is not included in the table, as there was necessarily some slight loss. The temperature of baking was about 400° F., which is just a little below the temperature at which the block-tin pipes would melt. The bread was baked in an ordinary oven over a gasoline stove.

---

[1] Determined by the diastase method.

[2] Minnesota Sta. Bul. 54, p. 48.

The results of the test are shown in the following table:

Loss of carbon dioxid in bread.

	Materials.			Carbon dioxid.		
	Flour.	Yeast.	Water.	Produced during rising.	Produced during baking.	Total.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Short-fermentation process:						
Bread No. 1	390	6.4	210	0.24	3.89	1.06
Bread No. 2	420	6.4	230	.29	3.86	1.09
Bread No. 3	390	6.2	230	.18	3.68	1.00
Bread No. 4[1]	385	6.1	230	[1].85	[1]5.35	[1]1.67
Average				.24	3.81	1.05
Long-fermentation process:						
Bread No. 5	410	3.30	230	1.025	2.41	.80
Bread No. 6	440	3.15	230	1.410	2.66	.90
Bread No. 7	400	3.25	230	1.100	2.58	.96
Bread No. 8	390	3.07	230	1.540	2.47	1.03
Average				1.300	2.52	.95

[1] Abnormal fermentation—omitted from averages.

From the table it appears that, on an average, about 1 per cent of carbon dioxid is produced and given off during bread making.

In the short-fermentation process the amount of carbon dioxid given off while baking exceeded by over 50 per cent the amount given off during the baking in the long-fermentation process.

In the long-fermentation process the amount of carbon dioxid given off while rising was about five times the amount given off during the same stage in the short-fermentation process.

Under the conditions in which these experiments were made the total loss of carbon dioxid was nearly the same for the two processes. In the case of abnormal fermentations, or prolonged fermentations at a higher temperature and under more favorable conditions, the loss of carbon dioxid may materially exceed 1 per cent.

In good bread making by either process the amount of carbon dioxid lost need not exceed 1 per cent.

LOSS OF CARBON IN THE FORM OF ALCOHOL.

During the fermentation process in bread making the production of carbon dioxid is accompanied by the production of alcohol. Theoretically, for every part of carbon dioxid gas formed there is also produced 1.04 parts of alcohol. It is generally supposed that during baking the alcohol is entirely given off. The theoretical amounts of alcohol formed during bread making in the above experiments, when calculated on the basis of the carbon dioxid evolved, would be as follows, in the short-fermentation process: (1) 1.10 per cent alcohol; (2) 1.13 per cent alcohol; (3) 1.04 per cent alcohol. Similar values for the long-fermentation process would be: (5) 0.83 per cent alcohol; (6) 0.94 per cent alcohol; (7) 1 per cent alcohol; (8) 1.07 per cent alcohol; general average, 1.02.

On an average there is about 1 per cent by weight of alcohol produced when bread is made. It serves a useful purpose. In baking the alcohol is volatilized and the vapor aids the carbon dioxid in expanding the dough, thus making the bread more porous. About 40 cubic centimeters of condensed products were obtained in flask *g*. When the contents of the flask was submitted to fractional distillation, no distillate was obtained until a temperature of nearly 90° was reached, showing that the alcohol was exceedingly dilute.

In several instances the amount of alcohol in the liquid recovered in the flask was determined by oxidation with chromic acid. The method followed was essentially that described by Blair[1] for the determination of carbon in iron by oxidation with chromic and sulphuric acids. Two additional U-tubes containing sulphuric acid were, however, added to the train to collect and retain acetic acid formed from incomplete oxidation of the alcohol. The acid in only one of the tubes was discolored. The contents of both tubes were then added to the generating flask and the oxidation completed. It is believed that this method secured practically all of the alcohol, as no unoxidized organic products could be detected.

The actual amounts of alcohol obtained by distillation and by the chromic acid method were less than half the theoretical amounts called for. Some of the alcohol had undoubtedly undergone chemical changes resulting in the formation of such bodies as organic acids. In one experiment 10 cubic centimeters of 95 per cent alcohol was added to the other ingredients in making the bread. The alcohol had no apparent effect upon the action of the yeast; the bread was in every way normal, except that an odor of alcohol was perceptible.

Samples of normal fresh bread were subjected to distillation and to other tests, but the distillate did not contain enough alcohol to give an appreciable reaction.

In general it may be said that there is on an average about 1 per cent of alcohol formed during bread making, and no appreciable amount of this alcohol is left in the bread.

LOSS OF CARBON AS OTHER VOLATILE COMPOUNDS.

In addition to carbon dioxid and alcohol, there is a small amount of carbon lost in other forms, such as volatile acids. If a bulb containing sulphuric acid is placed between the calcium chlorid tube *i* and the potash bulb *j* (fig. 1) it will be found that the sulphuric acid becomes dark colored, indicating that volatile compounds have been absorbed. The carbon thus obtained is probably formed from volatile organic acids. In four trials the carbon given off during baking, in the form of volatile organic matter, was determined. The volatile products, after removing the alcohol, were absorbed by sulphuric acid, and the carbon dioxid, to which they were equivalent, was determined by oxidation with chromic acid.[1] The amount of carbon dioxid thus obtained was: In sample No. 9, 0.10 per cent; No. 10, 0.14 per cent; No. 11, 0.07 per cent; and No. 12, 0.10 per cent. The result shows that some volatile organic matter containing carbon, either as hydrocarbons, volatile acids, or in other forms was given off during baking, and that the carbon thus obtained was equivalent to about 0.10 per cent of carbon dioxid.

---

[1] Iron Analysis, p. 149.

PRODUCTION OF SOLUBLE CARBOHYDRATES IN BREAD MAKING.

In wheat flour the carbohydrates are present mainly in the form of insoluble starch. There are, however, a number of other insoluble carbohydrates and small amounts of soluble carbohydrates, chiefly in the form of dextrin, with a small amount of sucrose.

A summary of the more important investigations on the insoluble and soluble carbohydrates of wheat, together with the results of a number of studies on this subject, has been recently reported by the Division of Chemistry of this Department.[2] From experiments of the Division of Chemistry and the best available data, normal air-dried wheat is said to contain insoluble carbohydrates as follows:

Average amount of insoluble carbohydrates in air-dried wheat.

	Per cent.
Starch	54.0–59.0
Free pentosans	3.5– 4.5
Lignin and its allies	2.0– 2.5
Cellulose	1.6– 2.1
Total insoluble carbohydrates	61.1–68.1

The soluble carbohydrates of wheat investigated by the Division of Chemistry were invert sugar, sucrose, and dextrin or galactin. The amounts of these constituents found in wheat and a number of wheat products are as follows:

Invert sugar, sucrose, and dextrin or galactin in wheat and wheat products.

Name.	Invert sugar.	Sucrose.	Dextrin.
	Per cent.	*Per cent.*	*Per cent.*
Wheat	0.027	0.330	0.160
Wheat flour	.014	.101	.190
Graham flour	.038	.382	.210
Self-raising wheat flours	.000	.056	.080
Miscellaneous wheat flours	.003	.098	.130
Common market wheat flours	.021	.288	.210
Bakers' and family flours	.027	.190	.220
Patent wheat flours	.002	.085	.200

---

[1] Blair, Iron Analysis, p. 149.

[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1192.

In addition to the soluble carbohydrates mentioned above, small amounts of raffinose have been reported by several investigators in wheat germs. Wheat germ contains more sucrose than any other of the wheat products, and the amount of soluble carbohydrates in wheat flour depends largely upon the proportion of germ present.

A sample of flour (No. 2) used in the experiments at the Minnesota Station to determine the extent to which starch is changed to soluble forms in bread making contained 1.62 per cent of soluble carbohydrates calculated as dextrin.

In addition to the production of alcohol and carbon-dioxid gas by fermentation, the action of the yeast and heat results in the production of soluble carbohydrates from insoluble forms. During the baking process the heat changes some starch to dextrin. In the process of bread making this results in both the consumption and production of soluble carbohydrates. The extent to which insoluble starch is changed to soluble forms in bread making is a subject which does not appear to have been extensively investigated. König[1] states that fine wheat bread contains 4.02 per cent sugar and coarse bread 2.08 per cent. The term sugar, however, is not defined.

The extent to which soluble carbohydrates are either consumed or produced during bread making is an important matter, because flour contains on an average 65 per cent or more of starch, and any change affecting the starch has a direct effect upon both the composition and value of the bread produced. In order to determine the extent to which soluble carbohydrates are produced, six experiments were made. In three experiments the bread was made by the short-fermentation process and in three other experiments by the long-fermentation process.

No attempt was made to separate and determine the different carbohydrates, as sucrose, dextrose, and dextrin. The separation of the soluble carbohydrates in flour, as a group, is a difficult matter. Flour contains soluble ferments which change some of the insoluble starch to soluble forms whenever flour is left in contact with water for any length of time.

The method used was as follows: Twenty grams of flour and 200 cubic centimeters of water were placed in a flask and thoroughly shaken. The water was left in contact with the flour for two hours and was then decanted into a filter of double thickness. A clear yellowish tinged filtrate was obtained, 100 cubic centimeters of which was submitted to hydrolysis and the dextrose determined in the usual way. For the bread 100 grams and 500 cubic centimeters of water were used. Concordant results could not be obtained with dilute solutions.

The details of each experiment are given in the following table, from which it will be observed that while the flour contains 1.62 per cent of

---

[1] Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 617.

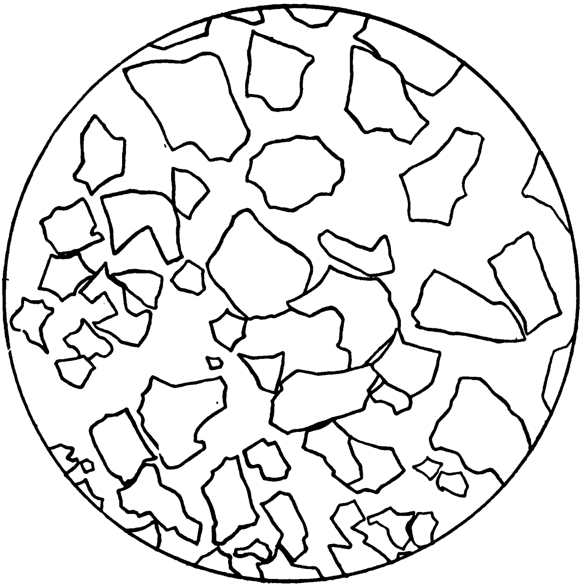


FIG. 1.—Appearance of starch grains in bread from flour ground in Dreef's Mill, magnified 110 diameters.

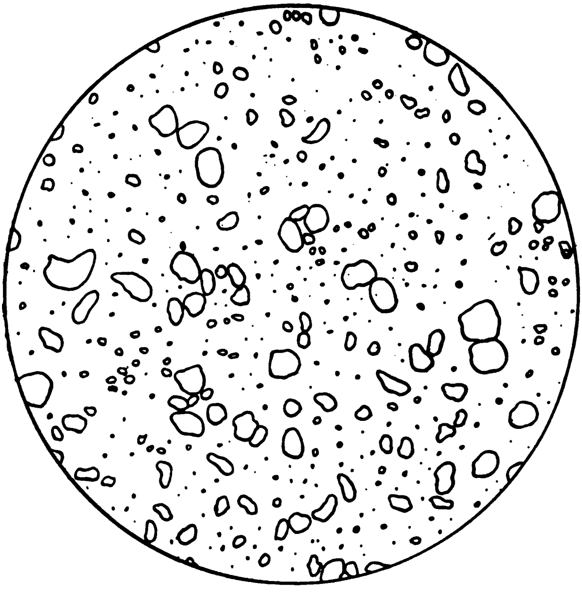


FIG. 2.—Appearance of starch grains in bread from flour ground in agate mortar, magnified 110 diameters.

APPEARANCE OF STARCH GRAINS IN BREAD.

soluble carbohydrates the fresh bread produced from the flour contained from 3.2 to 4.3 per cent.

Soluble carbohydrates of bread.

	Weight of flour used.	Weight of bread produced.	Soluble carbohydrates in bread.	Soluble carbohydrates in bread.	Soluble carbohydrates in flour.
Short-fermentation process:	*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Grams.*
Bread No. 13	290	415	3.3	13.70	4.70
Bread No. 14	284	399	3.3	13.17	4.60
Bread No. 15	280	393	4.3	16.90	4.54
Long-fermentation process:					
Bread No. 16	325	426	3.2	13.63	5.26
Bread No. 17	325	435½	3.4	14.79	5.26
Bread No. 18	325	427	3.5	14.94	5.26

Notwithstanding the loss of carbohydrates caused by the production of alcohol and carbon dioxid, these fresh breads contained from 3.2 to 4.3 per cent of soluble carbohydrates. Allowing for average losses of carbohydrates by fermentation, not far from 6 to 8 per cent of the total insoluble starch originally present in the flour has been changed to soluble forms during the bread-making process. There are other changes which the starch has undergone which are not shown by chemical analysis. By the combined action of the ferments and heat the forms of many of the starch grains in bread are materially changed. When bread is extracted with alcohol and water to remove a part of the proteids and the soluble carbohydrate bodies, the forms of the starch grains may be distinctly studied. The appearance of the starch grains in bread is shown in Pl. I.

Many of the starch grains appear as if they had been partially digested, and many pieces of disintegrated starch granules are present. In some cases the outer layers of the starch grains appear as if they had been subjected to pressure and partially ruptured. Many of the smaller and medium-sized grains appear unaltered. These physical changes which the starch grains have undergone during the bread-making process doubtless render bread (when properly made) more susceptible to the action of solvents, as the digestive fluids.

The changes which the carbohydrates undergo in bread making may be briefly summarized. They are both physical and chemical. Not far from 6 to 8 per cent of the insoluble starch is changed to soluble forms, while the combined action of the ferments and heat ruptures a large portion of starch grains, rendering them more susceptible to further changes.

PRODUCTION OF ACIDS IN BREAD MAKING.

Wheat bread made with yeast gives an acid reaction. The amount of acid varies with the quality of the yeast, the flour, and the conditions which govern the fermentation or rising process. Bread[1] is said to contain lactic, acetic, and occasionally butyric acids. The characteristic acid of wheat flour has, however, never been determined. For convenience the acidity is expressed as percentage amounts of lactic acid.

---

[1] Jago, The Science and Art of Bread Making, p. 366.

All wheat flours contain variable amounts of acid bodies. Calculated as lactic acid, the acidity of normal flour usually ranges between 0.09 and 0.15 per cent. In old and in musty flours the acidity may exceed 0.5 per cent.

For the determination of the acidity of flour, in the experiments which follow, 20 grams of flour and 200 cubic centimeters of water were placed in a flask and shaken vigorously. After the flour had been in contact with the water for an hour the solution was filtered and 50 cubic centimeters titrated with a tenth normal solution of potassium hydrate, using phenolphthalein as an indicator. Flour does not readily give up its acid to solvents.

The acidity of a number of samples of wheat flour and wheat products was determined with the following results, the acid being estimated as lactic acid:

Acidity of flour and other wheat products.

	Samples analyzed in 1897.	Per cent.
No. 1	Roller-process patent flour	0.09
No. 2	Spring wheat patent flour	.09
No. 3	Winter wheat patent flour	.09
No. 4	Roller-process flour, second grade	.12
No. 5	Musty flour	.46
No. 6	Red Dog flour	.54
No. 7	Wheat germ	.68

The acidity of the dough and of the bread of a number of samples made from the same flour was determined. The amount of acid (estimated as lactic acid) was determined in six samples of dough, six of fresh bread, and six samples of bread made by the short-fermentation process, which had been baked three days. The acid was also determined in three samples of sour-bread dough, five samples of fresh bread from the same dough, and in five samples of the bread which had been baked three days.

Acidity of dough and bread made in different ways.

	Short-fermentation process.						Sour-dough process.				
	Sample 1.	Sample 2.	Sample 3.	Sample 4.	Sample 5.	Sample 6.	Sample 1.	Sample 2.	Sample 3.	Sample 4.	Sample 5.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Dough	0.36	0.36	0.36	0.33	0.40	0.33	0.60	0.58	0.60	......	......
Fresh bread	.18	.20	.22	.12	.14	.16	.38	.36	.38	0.38	0.40
Bread three days after baking	.22	.27	.30	.20	.25	.27	.58	.44	.57	.59	.61

In the trials, the acidity of the dough made by the short-fermentation process was between 0.3 and 0.4 per cent. In sour dough, the acidity was about 0.5 per cent. The bread contains a lower percentage of acid than the dough. This appears to be due in part to the volatilization of some of the acid during baking, and also to the combination of the acid with other bodies in the bread (see p. 24).

In the first stages of fermentation the acidity of dough was found to be much less than in the last stages. When the alcoholic fermentation became less active, the acidity of the dough increased. The acidity of the dough also varies with the quality of the yeast. The acidity of both the bread and dough in the long-fermentation process was found to be greater than in the short-fermentation process. The results were calculated as lactic acid. Three samples were analyzed. No. 13 contained 0.12 per cent, No. 14 0.12 per cent, and No. 15 0.12 per cent of lactic acid. These samples were made by the short-fermentation process. Of the samples made by the long-fermentation process No. 16 contained 0.28 per cent, No. 17 0.30 per cent, and No. 18 0.32 per cent of lactic acid.

The presence of milk, and also the kind of milk, was found to have an appreciable effect upon the acid content of the bread, as may be observed from the following table, which shows the acidity of bread made with milk and the average acidity of bread made with water:

Acidity of bread made in various ways.

	Bread made with fresh milk.	Bread made with skim milk.	Bread made with sterilized skim milk.	Bread made with water (short fermentation).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Bread, fresh	0.09	0.135	0.09	0.17
Bread, 1 day old	.18	.18	.12	....
Bread, 2 days old	.16	.21	.13	....
Bread, 3 days old	.16	.21	.15	.25

The effect which acids have upon the food value of the bread is difficult to estimate. The loss in food value by the production of acids when the bread contains only about 0.2 per cent is not serious. In sour bread the losses by the formation of acids are much greater.

BEHAVIOR OF THE PROTEIDS OF WHEAT FLOUR IN BREAD MAKING.

In bread making the changes which the proteids undergo appear to have been less extensively studied than the changes which affect the carbohydrates. The part which the proteids take, however, seems of equal importance.

According to Osborne[1] the proteids of wheat are (1) an albumin soluble in water and coagulable by heat; (2) a globulin soluble in dilute salt solutions and coagulable by heat; (3) a proteose body soluble in water and not coagulable by heat; (4) gliadin soluble in dilute alcohol; and (5) glutenin which is insoluble in water, salt solutions, or dilute alcohol. The last two are present in larger quantity than the others, and together form the gluten of wheat and of flour.

---

[1] Amer. Chem. Jour., 15 (1893), pp. 468–471.

Wheat gluten is composed of 60 to 70 per cent gliadin and 30 to 40 per cent glutenin. The gliadin constitutes the binding material of the flour and enables the dough to retain the gas and to become light when the bread is made. A flour that contains an excess of gliadin is soft and sticky, while one deficient in this material is lacking in power of expansion. The glutenin is the material to which the gliadin adheres and thus prevents the dough from becoming too soft and sticky. In hard wheat flours the gluten is believed to be composed of gliadin and glutenin in the ratio of about 65 to 35,[1] while in the flours from soft wheats the ratio is 70 to 30.

A flour similar to the one used in these experiments and from the same source contained the following percentages of the several proteids:

Proteids in wheat flour.

	Per cent.
Albumin	0.3
Globulin	.9
Proteose body	.2
Gliadin	6.8
Glutenin	4.5
Total	12.7

The gluten of flour, independent of ferment action, possesses, when baked, a power of expansion varying with the quality of the flour from which the gluten is obtained. An apparatus for testing the expansive power of gluten of flour has recently been devised by C. M. Foster, of Minneapolis, and has been described in a publication[2] of the Division of Chemistry of this Department. As a general rule the better the baking qualities of the flour the greater the power of expansion. The illustration (fig. 3) shows the expansive power, as measured by Foster's apparatus, of the gluten from two samples of flour containing nearly the same percentage of total protein compounds but different percentages of gluten.

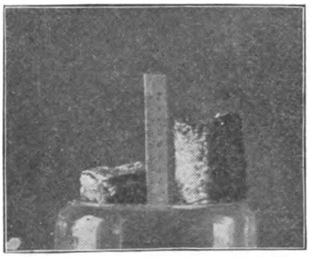


FIG. 3.—Gluten from two samples of flour.

The quality of gluten determines very largely the quality of the bread which is produced. Two samples of flour may contain about the same relative amounts of carbohydrates and proteid compounds, and

---

[1] Minnesota Sta. Bul. 54, p. 42.

[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1272.

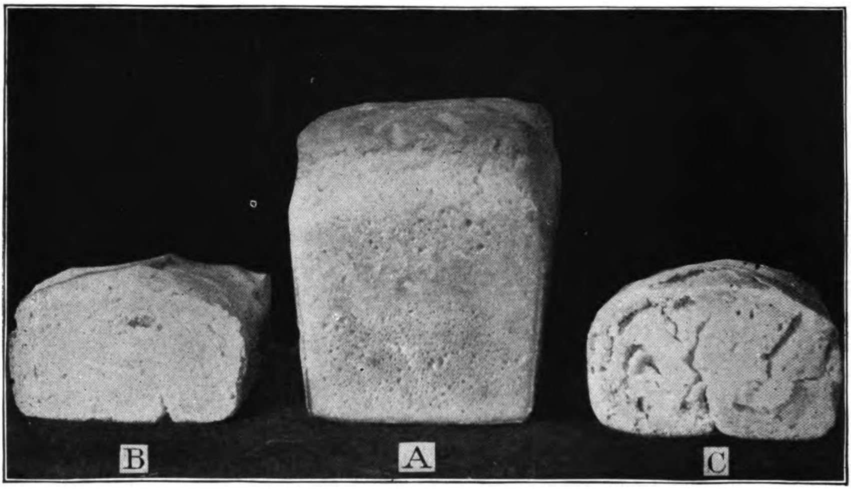


FIG. 1.—Bread from normal flour and from mixtures of normal and extracted flours: A, normal flour; B, flour with about one-half of the gliadin extracted; C, one-half normal and one-half gliadin-extracted flour.

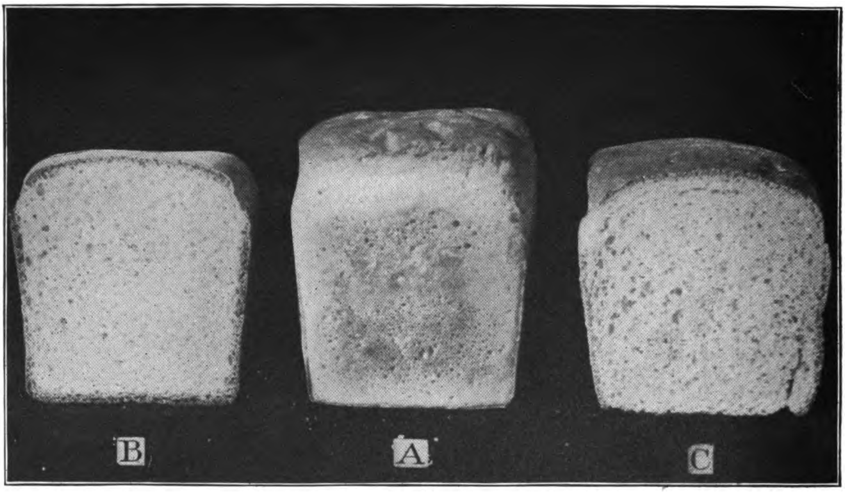


FIG. 2.—Bread from normal flour and from mixtures of normal and corn flours: A, normal flour; B, normal flour and 20 per cent corn flour; C, normal flour and 10 per cent corn flour.

BREAD FROM NORMAL FLOUR, FROM MIXTURES OF NORMAL AND EXTRACTED FLOURS, AND FROM MIXTURES OF NORMAL AND CORN FLOURS.

have about the same amount of gas produced during fermentation, and yet produce bread of entirely different physical properties because of the difference in the gluten in the two flours. The two samples from which the glutens shown in fig. 3 were prepared are flours which produce bread of entirely different physical properties. The percentage of carbohydrate and protein compounds in the two samples are nearly the same, but the glutens are entirely different, as the illustration indicates.

As stated above, the quality of the bread is determined very largely by the relative proportion of gliadin and glutenin in the gluten. In order to produce the best quality of bread the gliadin and glutenin must be present in the right proportion to form a balanced gluten. This fact can best be illustrated by noting the effect produced by removing a part or all of the gliadin. The gliadin from a sample of high-grade patent flour was removed by extraction with alcohol, and when bread was made from the gliadin-extracted flour the dough was not sticky. It felt like putty and broke in the same way. The yeast caused the mass to expand a little when first placed in the oven, then the top of the loaf began to break apart, and there was a decrease in size. The result was a loaf of less than half the size of that made from the same weight of normal flour. On the other hand, when the water-soluble proteids were extracted from normal flour the bread was normal in appearance. When the globulin was extracted the bread was also normal. The bread, however, produced from flour which had been extracted with water, and with dilute salt solutions, was nearly tasteless, probably due to the removal of the soluble carbohydrates and other fermentation products. (See Pl. II.)

The removal of a part of the gliadin also resulted in producing nearly the same effect as the removal of all the gliadin. A sample of flour containing 1.95 per cent total nitrogen and 1.23 per cent gliadin-nitrogen was partially extracted with alcohol. The extracted flour contained 1.41 per cent total nitrogen. The bread produced from this flour was very similar to that produced when all of the gliadin was extracted. When half normal flour and half of the partially extracted flour were mixed the bread product was only slightly improved. Three trials at different times gave substantially the same results. From these experiments it is evident that any interference with the gliadin-glutenin ratio in flour has a marked influence upon the quality of the bread product. When the gliadin-glutenin ratio was left undisturbed a foreign proteid could be introduced without materially interfering with the rising of the bread. Bread made with 10 per cent corn flour and 90 per cent patent wheat flour had nearly the same coefficient of expansion as bread made from normal flour.

From these experiments it would appear that as long as the gliadin-glutenin ratio remains normal it is possible to reduce slightly the percentage amounts of these two proteids without materially influencing the expansion coefficient of the dough, but any material change of the gliadin-glutenin ratio materially influences the power of the dough to expand and produce a good quality of bread.

Inasmuch as the protein compounds are subject to changes during the bread-making process and any changes affecting the gluten proteids may affect the physical properties of the bread, it follows that the part which the proteids take in bread making is an important one. It was therefore studied in considerable detail.

In this investigation flour (No. 2) of the following composition was used: Water, 9.74 per cent; protein (N × 5.7), 11.80 per cent; ether extract, 0.92 per cent; soluble carbohydrates, 1.62 per cent; starch,[1] 68.80 per cent; ash, 0.46 per cent; undetermined, 6.54 per cent, and acidity (as lactic acid), 0.12 per cent.

The plan followed was to determine the solubility of the nitrogen in the flour, in the dough, and in the bread, since during the process of bread making the proteids are acted upon by (1) ferments, (2) by acids produced during the fermentation, and (3) by heat. The question naturally suggests itself: To what extent does the combined action of these three agents affect the composition of the proteids?

The solubility of the nitrogenous compounds expressed in terms of nitrogen was as follows, the total nitrogen being 2.07 per cent: Water-soluble nitrogen (albumin, proteose, etc.), 0.32 per cent; salt-soluble nitrogen (globulin), 0.12 per cent; alcohol-soluble nitrogen (gliadin), 1.31 per cent.

The two proteids, gliadin and glutenin, are both soluble in dilute acid and alkaline solutions, gliadin being more soluble in acid than glutenin.

Independent of all ferment action, the proteids seem to be acted upon by the acid bodies produced during the fermentation. There appears to be a partial union between the acid and the proteid bodies. The fact that flour can, in some way, absorb acid bodies was demonstrated in the following way: Ten cubic centimeters of a dilute solution of lactic acid (containing 0.549 gram) was introduced into a flask containing 10 grams of flour and 90 cubic centimeters of water. After being in contact with the flour for an hour only 0.441 gram of lactic acid could be obtained by titration, showing that 10 grams of flour had absorbed 0.108 gram of the acid. That this absorption was somehow connected with the proteid bodies was shown by separating the gluten from 10 grams of flour and placing it in a flask with 10 cubic centimeters of dilute lactic acid (containing 0.549 gram). Only 0.443 gram of acid was recovered. Hydrochloric and other acids are absorbed in a similar way. In order to determine the extent to which the acids in the dough act upon the proteids, weighed quantities of flour were subjected to the action of dilute solutions (0.22 per cent) of lactic acid. The results are as follows:

---

[1] Estimated by the Lindet method.

Effect of lactic acid upon proteids of flour.

	Lactic acid used.	Nitrogen of proteids rendered soluble.
	Per cent.	*Per cent.*
Flour No. 1	0.22	0.43
Flour No. 2	.44	.48
Flour No. 3	.55	1.12

With a dilute lactic-acid solution proteid equal to 0.43 per cent of nitrogen, in excess of water-soluble proteid, was dissolved.

When a given amount of acid was added to a definite weight of gluten, not all of the acid could be recovered by subsequent titration with a standard alkali solution. The acid, however, rendered some of the proteid more soluble. These facts would indicate that the acid and the proteid had formed a soluble compound, and that the acid was held in such a firm state of combination that it could not subsequently be combined with an alkali. A similar reaction takes place in the manufacture of "sweet-curd" cheese. The milk before it is coagulated contains a much higher percentage of acid than the whey. The small amount of acid combined with the milk proteids can not be recovered with an alkali. The observation of Nasse,[1] confirmed by Schützenberger, that a certain fraction of the nitrogen of proteids is in less stable forms of combination than the rest, offers in part an explanation of the behavior of gluten proteids in acid solutions.[2]

The acid of 0.55 per cent strength, which corresponded to the strength of the acid found in the sour dough (flour No. 3), dissolved 1.12 per cent nitrogen. Under ordinary conditions the acids formed during bread making, independent of ferment action, are capable of dissolving about 0.5 per cent nitrogen.

The amounts of water-soluble nitrogen found in doughs of various degrees of acidity are shown in the following table:

Soluble nitrogen in doughs of different acidity.

	Acidity.	Soluble nitrogen.
	Per cent.	*Per cent.*
Dough No. 1	0.25	0.50
Dough No. 2	.20	.41
Dough No. 3	.40	.52
Dough No. 4	.60	1.20

---

[1] Watts, Dictionary of Chemistry, Proteids, Vol. IV, p. 328.

[2] Since this bulletin has been prepared for the press, Osborne (Jour. Amer. Chem. Soc., 21 (1899), p. 486) has published an article "Definite compounds of protein bodies," in which he states, page 493, that "what has heretofore been regarded as 'native' protein substances are, in fact, protein bodies combined to acids, so that preparations as usually obtained have been mixtures of simpler salts of these bodies." This statement is in harmony with the facts reported in this bulletin.

It is to be observed that the amount of soluble nitrogen in doughs increases with the acidity of the dough, and that the solvent action of the acids accounts for nearly all the soluble nitrogen. This would indicate that the ferment bodies have not directly acted upon the proteids to any appreciable extent but that the acid products of fermentation have rendered some of the proteids soluble. In the most acid dough the amount of soluble nitrogen was found to be 1.20 per cent.

The fact that the proteids of the dough are of a different nature from the proteids of flour can be shown by placing about 30 grams of acid dough in a linen bag and attempting to obtain the gluten by washing. Only about a third as much is obtained as from the same amount of flour, showing that the gluten of the dough has undergone marked changes.

When bread is baked the heat changes the solubility of some of the proteids. The albumin and the globulin are both coagulated at the temperatures reached in baking, and are changed from water-soluble and salt-soluble to insoluble forms.

The water-soluble nitrogen in six samples of bread was determined. In three of the breads, samples 1, 2, and 3, made by the short-fermentation process, there was a low acidity, while in three other samples, 4, 5, and 6, made by the long-fermentation process, the acidity was high. The alcohol-soluble or gliadin nitrogen was also determined. The results are given, on the basis of the dry matter, in the following table:

Soluble nitrogen in bread.

	Acidity.	Total nitrogen.	Water-soluble nitrogen.	Alcohol-soluble nitrogen.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Short-fermentation process:				
Bread No. 1	0.13	2.30	0.11	....
Bread No. 2	.13	2.26	.10	1.31
Bread No. 3	.13	2.30	.11	1.26
Long-fermentation process:				
Bread No. 4	.60	2.30	.50	.77
Bread No. 5	.60	2.26	.55	.75
Bread No. 6	.61	2.28	.50	....

Breads made from doughs of low acidity contain only a small amount of water-soluble nitrogen. But little nitrogen is rendered soluble in the dough, and the albumin and globulin are coagulated during the baking.

When a high acidity is reached in the dough the amount of water-soluble nitrogen produced in the bread is increased. This is due apparently to the solvent action of the acid produced during the rising process.

From the table it appears that the gliadin is probably the proteid which is rendered soluble, as there is a decrease of alcohol-soluble nitrogen and a proportional increase of water-soluble nitrogen.

It is a well-known fact that in order to produce good bread from some flours a longer fermentation is necessary than from other flours. The longer fermentation undoubtedly reduces the gliadin content, so that the proportions between the gliadin and the glutenin are better suited for bread making.

It is generally considered that yeast is used in bread making simply for the purpose of producing gas to expand the dough. In some flours, however, yeast has an additional action, namely, to produce acid bodies which combine with the gliadin to form acid proteids, so that the ratio between the remaining gliadin and glutenin becomes more or less favorable for the production of a good quality of dough. Hence the same method of bread making does not produce the same results with all flours because of the differences in the composition of the gluten in the various flours.

LOSS OF NITROGEN IN BREAD MAKING.

Proteids constitute about 97 per cent of the total nitrogenous material of flour. In addition, flour contains nitrogen in other forms, as amid nitrogen. The amount of amid nitrogen is small, usually ranging from 0.02 to 0.08 per cent. The amid compounds do not constitute so stable a group as the proteids. In bread making the more stable protein compounds undergo only a limited change in solubility, as discussed in the preceding section; the amid compounds may, however, be converted into ammonia and lost.

The two factors which affect the loss of nitrogen in bread making are (1) the amount of nonproteid nitrogen in the flour, and (2) the nature of the fermentation. When bread is made from flour containing only a small amount of amid nitrogen, and the fermentation is of such a nature that amid compounds are not formed from soluble proteids, the amount of nitrogen lost is small.

There are at least two ways by which the amount of nitrogen lost during bread making may be determined: (1) by analyzing the flour and bread, to determine the amount of nitrogen obtained in bread made from a known weight of flour, and (2) by analyzing the gaseous products evolved during the process of bread making. In this work both methods were employed. Two series of investigations were made, one in 1897 and one in 1898. The work of the first year was of a preliminary nature. In 1897 bread was made from flour which contained 2.09 per cent nitrogen; in 1898 bread was made from flour which contained 2.07 per cent of total nitrogen, and 0.3 per cent amid nitrogen. The first method of procedure was as follows: A portion of flour (300 to 400 grams), more than sufficient for the required amount of bread, was weighed. The bread was made by the short-fermentation process, mechanical losses of flour being avoided as much as possible. The amount of unused flour was weighed and deducted from the original amount. The same amount of yeast and water was used for each loaf.

In the following table is shown the weight of materials used and of the bread obtained in 1897, when the short process of fermentation was employed:

Weight of materials used and bread made by short-fermentation process in 1897.

	Flour.	Water.	Yeast.	Bread.
	Grams.	*Cc.*	*Grams.*	*Grams.*
Bread No. 1	353.57	230	6.85	512.76
Bread No. 3	368.34	230	6.27	520.70
Bread No. 5	322.28	230	6.57	445.10

The dry matter and nitrogen in the material and bread, and the actual and percentage losses are shown in the following table:

Dry matter and nitrogen in materials used and bread made by short-fermentation process in 1897.

	Dry matter.						Nitrogen.					
	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.
	Gr.	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*
Bread No. 1 ..	315.20	2.36	317.56	312.94	4.62	1.48	7.39	0.14	7.53	7.23	0.30	3.94
Bread No. 3 ..	328.36	2.16	330.52	322.05	4.75	1.43	7.69	.13	7.82	7.81	.01	.13
Bread No. 5 ..	287.30	2.26	289.56	286.90	2.66	.92	6.74	.13	6.87	6.76	.11	1.60

When bread was made by the long-fermentation process in 1897 the weight of the materials used and of the bread made was as follows:

Weights of materials used and bread made by long-fermentation process in 1897.

	Flour.	Water.	Yeast.	Bread.
	Grams.	*Cc.*	*Grams.*	*Grams.*
Bread No. 2	378.20	230	1.68	490.1
Bread No. 4	390.67	230	2.66	525.7
Bread No. 6	435.82	230	2.45	553.6
Bread No. 7	415.7	230	2.35	566.1

The dry matter and nitrogen in the materials used and the bread made, as well as the actual and percentage losses of dry matter and nitrogen, are shown in the following table:

Dry matter and nitrogen in materials used and bread made by long-fermentation process in 1897.

	Dry matter.						Nitrogen.					
	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.
	Gr.	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*Gr.*	*P. ct.*
Bread No. 2 ..	337.15	0.59	337.74	310.28	27.46	8.14[1]	7.90	0.03	7.93	7.057	0.880	11.09[1]
Bread No. 4 ..	348.27	.92	349.02	313.30	35.70	10.23[1]	8.17	.05	8.22	7.730	.488	5.94
Bread No. 6 ..	388.52	.85	389.37	362.50	26.87	6.90	9.11	.05	9.16	8.304	.856	9.29[1]
Bread No. 7 ..	370.58	.81	371.39	355.34	16.05	5.93	8.69	.05	8.74	8.208	.532	6.016

[1] Abnormal losses.

In 1898 practically this same method was followed. The bread was weighed when fresh and was again weighed after standing eighteen hours. It was then prepared for analysis.

The weight of the ingredients used in making the bread, the weight of the dough and bread, and the percentage of water in the bread are shown in the following table:

Weight of ingredients and dough and percentage of water in bread made by short-fermentation process in 1898.

	Materials used.			Dough when mixed.	Dough when kneaded.	Fresh bread.	Bread 18 hours old.	Water in bread 18 hours old.
	Flour.	Water.	Yeast.					
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Bread No. 8........	290	172	4.5	456.9	456	425.3	415	37.23
Bread No. 9........	284	172	4.5	450.5	445	408.4	398.8	36.16
Bread No. 10.......	280	172	4.5	444.7	442.2	402	392.8	36.78

After the second weighing each loaf was cut into halves and the two portions analyzed separately by different analysts. A quarter of a loaf was used for the moisture determination, and it was found that concordant results could not be obtained by crumbing the bread and using a weighed quantity of the mixed crumbs for the determination of moisture. The amount of moisture present in different parts of a loaf of bread is extremely varied, as the following determinations show: Water in crust, 22.29 per cent; water in crumb, 40.65 per cent; water in different parts of the crumb, 38.77, 42.95, and 42.01 per cent.

Nitrogen determinations were made with the fresh bread, and the dried material after it had been pulverized and thoroughly mixed. The most satisfactory results were obtained by using the dry material. Unless otherwise stated, all the results were obtained from the analysis of such material.

The composition of the bread (water-free substance) made by the short-fermentation process in 1898 was as follows:

Composition of bread made by short-fermentation process in 1898.

	Dry matter.					
	Protein (N×5.7).	Ether extract.	Soluble carbohydrates.	Insoluble carbohydrates.	Ash.	Acidity.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bread No. 8..................................	13.11	0.37	5.25	80.70	0.44	0.13
Bread No. 9..................................	13.11	.44	5.25	80.60	.47	.13
Bread No. 10.................................	12.88	.42	6.80	79.29	.48	.13

The yeast had the following composition: Water, 64.53 per cent; ether extract, 0.44 per cent; total nitrogen, 1.65 per cent; carbohydrates, 23.26 per cent, and ash, 1.46 per cent.

The dry matter in the materials and in the bread made from them, as well as the actual and percentage loss of dry matter, are shown in the following table:

Total dry matter in materials and bread made by short-fermentation process in 1898.

	Flour.	Yeast.	Total.	Bread.	Loss.	Loss.	Average loss.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*
Bread No. 8	261.7	1.6	263.3	260.5	2.8	1.07	1.58
Bread No. 9	256.3	1.6	257.9	254.6	3.3	1.28	
Bread No. 10	252.7	1.6	254.3	248.3	6.0	2.38	

The nitrogen in the materials and bread made from them, together with the actual and percentage loss of nitrogen, are shown in the following table:

Total nitrogen in materials and bread made by short-fermentation process in 1898.

	Flour.	Yeast.	Total.	Bread.	Loss.	Average loss.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Gram.*	*Per cent.*
Bread No. 8	6	0.07	6.07	5.99	0.08	1.45
Bread No. 9	5.87	.07	5.94	5.88	.06	
Bread No. 10	5.80	.07	5.87	5.75	.12	

Under the conditions of these experiments there was an average loss of 1.58 per cent of total dry matter and 1.45 per cent of the total nitrogen. The difference between the amount of nitrogen in the bread and that in the flour and yeast is so small that it might well be questioned whether this loss is not within the limits of error of ordinary chemical work. In order to check the results, the gases evolved during bread making were analyzed. The general arrangement of the apparatus used was much the same as that employed in collecting the carbon dioxid (see p. 12). A U-tube containing sulphuric acid was substituted for the potash bulbs. After the gas evolved had passed through the apparatus, the contents of the flask *g* and of the U-tube were transferred to a Kjeldahl flask and the nitrogen determined in the usual way. Four determinations were made. The amount of nitrogen given off from 300 grams of flour was found to be small, about 0.02 per cent. When the bread was dried in the drying oven a larger amount of nitrogen was given off than during the baking process. Twenty-five one-hundredths gram of bread when dried yielded from 0.01 to 0.02 per cent nitrogen. It is to be observed that while the two methods do not absolutely agree as to the amount of nitrogen lost, there is, however, a slight loss observable in each case. When bread is properly made, this loss of nitrogen need not seriously affect its nutritive value.

To obtain additional information on this matter determinations of the nitrogen in the crust and crumb were made with a sample of each. The complete analysis of the samples is also reported. On the basis of dry matter the amount of nitrogen found was practically the same in both.

Composition of crust and crumb.

	Water.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Nitrogen in dry matter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crust	22.29	11.43	0.60	65.30	0.38	2.35
Crumb	40.65	8.87	.49	49.67	.32	2.39

While the amount of nitrogen lost when bread is properly made is small, the amount lost when bread is not properly made may materially exceed the figures given above.

In order to determine to what extent losses may occur under abnormal conditions, or what are frequently usual conditions, bread was made without any special care, except to avoid mechanical losses. The long-fermentation process was followed, the same flour being used as in the tests by the short-fermentation process. A batter was made in the afternoon and the bread raising completed the next day about noon. A strongly acid dough resulted. The weight of flour and of the bread made, together with its content of water, are given in the following table:

Weight of material and bread, and of water in bread, made by long-fermentation process in 1898.

	Materials.			Fresh bread.	Water in fresh bread.
	Flour.	Yeast.	Water.		
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Bread No. 11	325	2.2	172	437.2	35.03
Bread No. 12	325	2.2	172	435.5	36.68
Bread No. 13	325	2.2	172	427	35

Composition of bread made by long-fermentation process in 1898.

	Dry matter.					
	Protein (N × 5.7).	Ether extract.	Soluble carbohydrates.	Insoluble carbohydrates.	Ash.	Acidity.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bread No. 11	13.11	0.1	4.93	80.8	0.49	0.57
Bread No. 12	12.88	.3	5.25	80.46	.52	.59
Bread No. 13	13	.17	5.49	80.21	.52	.61

The loss of dry matter and nitrogen in the bread made is shown in the following table:

Dry matter and nitrogen in materials used and bread made by the long-fermentation process in 1898.

	Dry matter.					Nitrogen.				
	In flour.	In yeast.	Total.	In bread.	Loss.	In flour.	In yeast.	Total.	In bread.	Loss.
	Grams.	*Gram.*	*Grams.*	*Grams.*	*Per ct.*	*Grams.*	*Gram.*	*Grams.*	*Grams.*	*Per ct.*
Bread No. 11	293.3	0.8	294.1	276.8	5.88	6.73	0.03	6.76	6.37	5.77
Bread No. 12	293.3	.8	294.1	275.6	6.29	6.73	.03	6.76	6.22	7.98
Bread No. 13	293.3	.8	294.1	277.5	5.64	6.73	.03	6.76	6.32	6.5

It will be observed that by excessive fermentation resulting in the production of acid dough, there may be a loss of 5 per cent or more of dry matter. When some of the same flour was made into bread by less fermentation and with more care, the loss of dry matter was only 1.58 per cent, as noted above.

These figures indicate that in good bread making it is possible to reduce the losses caused by fermentation to about 3 pounds of flour per barrel. When less care is exercised the loss may be as high as 12 pounds of flour per barrel.

Von Bibra[1] states that there is less nitrogen in the crust of bread than there is in the crumb. According to this author the crumb of wheat bread contained 1.498 per cent nitrogen and the crust 1.363 per cent, while the crumb of rye bread contains 1.476 per cent and the crust 1.293 per cent.

In making bread; milk or lard is usually added to the dough. The effect upon the composition of the bread may be observed from the following table, which shows the composition of bread made with and without these ingredients:

Composition of flour, and bread made from it in different ways.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Flour	10.11	12.47	0.86	76.09	0.47
Bread made with water	36.12	9.46	.40	53.70	.32
Bread made with lard	37.70	9.27	1.02	51.70	.31
Bread made with skim milk	36.02	10.57	.48	52.63	.30

CHANGES IN THE SOLUBILITY OF FAT DURING BREAD MAKING.

It has frequently been observed that the ether extract of bread made of flour and water only is much lower than the ether extract in the flour from which it was made.[2] In flour No. 2 there was 0.96 per cent of ether extract. In none of the breads made from this flour was there more than 0.44 per cent of ether extract obtained (calculated on the dry matter basis). That is, of the total ether extract in the flour, not more than half was obtained as ether extract in the bread. Before extraction with ether the bread was dried at 100° in hydrogen.

In flour No. 2 the fat obtained was light colored, while that from the bread was decidedly dark colored and separated in the form of globules. During the process of bread making and drying there had evidently been some change affecting the composition of the fat, rendering it less soluble. The iodin absorption number of the fat from the flour and from the bread was determined. That of fat from flour was 101.4 and that of fat from bread, 60.4.

---

[1] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3d ed., 1889, vol. 2, p. 614.

[2] U. S. Dept. Agr., Office of Experiment Stations Buls. 35 and 52.

SUMMARY.

The results of these investigations may be summarized as follows:

(1) In ordinary bread making about 1 per cent of carbon dioxid was given off during the rising and baking processes and a little more than 1 per cent of alcohol was formed. There was also given off during baking a small amount of volatile acid products.

(2) The determination of the volatile products given off during bread making showed a total loss of 0.74 per cent of the total carbon in the flour, which is equivalent to about 1.68 per cent of starch.

(3) When special care was taken in bread making, the analyses of the flour and the bread showed an average loss of 1.58 per cent of the total dry matter of the flour.

(4) The analyses of the gases produced, and of the flour and bread, indicate that for good bread making the total losses need not exceed 2 per cent of the flour used, and that it is possible to reduce the losses to 1.1 per cent.

(5) The amount of alcohol recovered in bread making was found to be less than the theoretical amount corresponding to the carbon dioxid produced. This discrepancy is not due to alcohol remaining in the loaf, since no appreciable amounts of alcohol were recovered from fresh bread. When alcohol was used in making bread the action of the yeast was apparently normal.

(6) In bread making the starch undergoes both physical and chemical changes. From 3 to 4 per cent of soluble carbohydrates were found in the bread, indicating that less than 8 per cent of the total starch was changed from insoluble to soluble forms. The physical changes which many of the starch granules undergo are marked. Some are partially disintegrated, while others are ruptured.

(7) Normal flour contains a small amount of acid. During bread making variable amounts of acid was produced by the action of the yeast. A part of the acid formed appears to unite with the proteids. In acid doughs the acid renders the proteids more soluble and changes the composition of the gluten.

(8) When bread is made from dough of low acidity there was less water-soluble nitrogen in the bread than in the flour, because of the coagulation of the albumin and globulin during baking. In bread made from doughs of high acidity the amount of water-soluble nitrogen was increased. This is due to the action of the acid on the insoluble proteids. The gliadin is rendered soluble, which changes the gliadin-glutenin ratio of the bread.

(9) The power of expansion which the gluten of a flour possesses determines very largely the physical properties of the bread. Some glutens possess an expansive power four or five times greater than others.

In general it may be said that in good bread making the loss of dry matter and of nitrogen need not exceed 1.6 per cent of the total amounts in the flour. In poor bread making the losses may exceed 6 per cent. In good bread making the losses are equivalent to about 3 pounds per barrel of flour, while with poor bread making the losses may exceed 12 pounds per barrel.

DIGESTIBILITY OF BREAD.

Two experiments on the digestibility of bread were made with a healthy man, a university student, about 22 years old. He had been accustomed to ordinary farm labor. During the experimental periods the exercise consisted of a daily walk of 4 miles. In the first experiment bread made from patent roller-process flour ground from Scotch Fife (a spring wheat) was eaten, and in the second, bread made from the bakers' grade of flour from the same wheat was used. In milling wheat by the patent-roller process the finest grade flour is the flour first removed; the product next obtained is the bakers' grade. It is ground nearly as fine as the patent flour, and differs from it mainly in the physical qualities of the gluten. The bread used in the tests was made by the quick-fermentation process described on page 14, with milk, butter, and salt in addition to the yeast and flour. In both tests eggs and butter were eaten in addition to the bread. Each test covered two days and practically the same amounts of bread, butter, and eggs were consumed daily. The usual experimental methods were followed. The feces were separated by means of charcoal.[1] The composition of the two sorts of flour, the bread made from them, and of the butter and eggs, is shown in the following table:

Composition of flour, bread, eggs, and butter.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Patent roller-process flour	12.36	12.44	1.62	73.07	0.51
Bread from patent roller-process flour	32,80	9.06	3.53	53.99	.62
Bakers' grade flour	8.01	15.50	2.22	73.52	.75
Bread from bakers' grade flour	38.25	10.81	2.13	47.79	1.02
Eggs	74.22	15.21	9.88	....	.92
Butter	10.98	....	86.12	....	....

The food consumed in the two days of the first experimental period was as follows: First day, 672 grams patent flour bread; 5 eggs (net weight, 242.3 grams); 84 grams butter. Second day, the same quantity of bread and butter, and 4 eggs (net weight, 201.1 grams). The feces weighed 274.5 grams. The ether extract of the feces was found to contain some nitrogen; this was believed to be nitrogen of metabolic products. However, since it was not possible to settle this point definitely, no correction was made for it in determining the coefficients of digestibility. The dry matter of the feces weighed 62 grams and had the following percentage composition: Total ether extract, 19.57; nitrogen in ether extract, 0.42; protein, 28.94; carbohydrates, 36.99, and ash, 14.50. The constituents of the food consumed and of the feces and the coefficients of digestibility of the mixed diet are shown in the following table:

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 58.

Digestibility of diet containing bread made from patent roller-process flour.

	Dry matter.	Protein.	Fat.	Carbohydrates.
	Grams.	*Grams.*	*Grams.*	*Grams.*
In 443.4 grams of eggs	114.3	67.4	43.8	....
In 168 grams of butter	149.7	....	146.3	....
In 1,344 grams of bread	853.9	121.76	37.3	725. 6
Total	1,117.9	189.2	227.4	725.6
In 62 grams (dry) feces	62.0	17.9	12.1	22.9
Amount digested	1,055.9	171.3	215.3	702.7
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Coefficient of digestibility	94.4	90.5	94.7	96.9

On the first day of the second experimental period the ration was as follows: 652 grams bread, made from bakers' grade of flour; 218.6 grams eggs; and 84 grams butter. On the second day, 672 grams bread, 242.3 grams eggs, and 84 grams butter. The feces weighed 279 grams. The dry matter of the feces weighed 62.5 grams and had the following percentage composition: Total ether extract, 19.05; nitrogen in ether extract, 0.40; protein, 30.94; carbohydrates, 32.49, and ash 17.52. The constituents of the food and feces and the coefficients of digestibility of the different nutrients are shown in the following table:

Digestibility of diet containing bread made from bakers' grade flour.

	Dry matter.	Protein.	Fat.	Carbohydrates.
	Grams.	*Grams.*	*Grams.*	*Grams.*
In 1,324 grams bread	817.6	143.1	28.2	632.7
In 461 grams eggs	118.9	70.1	45.6	....
In 168 grams butter	149.6	....	144.7	....
Total	1,086.1	213.2	218.5	632.7
In feces	62.5	19.3	11.9	20.3
Amount digested	1,023.6	193.9	206.6	612.4
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Coefficient of digestibility	94.2	91.0	94.6	96.8

It will be seen that the coefficients of digestibility of the mixed diet in the two experimental periods were practically the same. Since practically the same amounts of eggs and butter were consumed in each period, and the only varying factor in the diet was the bread, it seems fair to assume that the two sorts of bread had the same digestibility. The experimental periods were of short duration, and the data are doubtless insufficient for general deductions. The experiments do, however, indicate that there is no marked difference in the digestibility of bread made from the two sorts of flour.

At the beginning of the first test the subject weighed 159 pounds, and at the close 159¾ pounds. His weight at the beginning of the second test was 164½ pounds, and at the close 165 pounds—that is, in each experimental period the weight remained practically constant.

During the first test 1,615.4 grams urine was excreted, containing 1.67 per cent nitrogen, and during the second test, 1,714 grams, containing 1.69 per cent of nitrogen. The daily income of nitrogen in the first test was 15.1 grams, the outgo in the urine 13.5 grams, and in the feces 1.4 grams—that is, there was a daily gain of 0.2 gram nitrogen. In the second test the daily income of nitrogen was 17.1, the outgo in the urine 14.5, and in the feces 1.5. The subject therefore gained 1.1 grams nitrogen per day.

Summing up the results of the tests, it may be said that, as far as can be judged from coefficients of digestibility, changes in weight of the subject, and balance of income and outgo of nitrogen, no differences were observed when bread made from fine patent roller-process flour and bread from first bakers' grade of flour made from the same wheat was consumed by a healthy man.

LOSSES IN THE PROCESS OF MAKING BREAD.

By L. A. Voorhees, M. A.,
Chief Chemist, New Jersey Agricultural Experiment Station.

INTRODUCTION.

When flour is made into bread, it is subjected to the action of ferments (yeast) and heat. It is well recognized that these agents produce changes in the constituents of the flour, but the character and extent of the changes are not definitely known. Blyth[1] describes bread making, and speaks of the changes which take place, as follows:

> Wheaten bread is the flour of wheat made into a paste with water, and the paste is permeated by carbon dioxid either by adding yeast, which causes a true fermentation with the production of alcohol and carbon dioxid, or the carbon dioxid is added in solution in water to the paste, as in Daughlish's system. The explanation of the bread-making process is not thoroughly worked out in all its details, but the following theory agrees fairly well with what is witnessed: On adding yeast to the dough it is placed on one side at a suitable temperature and allowed to rise—that is, fermentation proceeds, and there is a continual evolution of gas; the starch in some degree becomes changed into sugar, which sugar is decomposed into carbon dioxid and alcohol. The gluten prevents or rather retards the escape of the carbon dioxid, and the tension of the warm gas expands little cells and gives to the bread its familiar light, spongy appearance. The alcohol mostly escapes. * * * The outside of the loaf when placed in the oven is raised to a temperature of from 210° to 212°C., but the crumb is seldom much above 100°. The crust is to some extent caramelized. * * * In the crust there is a partial destruction of the nitrogenous substance. Thus Von Bibra found that the crumb of wheaten bread contained 1.498 per cent of nitrogen and the crust 1.363 per cent. The crumb of rye bread contained 1.476 per cent of nitrogen and the crust 1.293 per cent. * * * The fatty matters are not, as far as is known, changed. The ash is not changed save by the minute proportion of yeast ash which is added to it, an addition quite inappreciable. Further, any salt added by the baker increases a little its weight, but the ordinary method of burning bread volatilizes very effectually chlorids of the alkalies, so that the ash of bread is still very small.

In a publication of the Division of Chemistry[2] of this Department, the following statements are made:

> The loss of solid matter during the fermentation and baking of the bread is due to the conversion of part of the solid matter into volatile substances and their evapora-

---

[1] A. W. Blyth, "Foods: Their composition and analysis," ed. 1888, p. 171.

[2] U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1317.

tion during the process of baking. The only substances which are changed in any appreciable degree by this process are the sugars which the flour may contain. It is evident, therefore, that the loss in no case can be greater than is due to the fermentation of the sugars. It is not probable that any large quantity of sugar will be formed from the starch during the fermentation process. * * *

It must be admitted, moreover, that not all of the sugar which is present in a flour is decomposed during the process of fermentation, unless the period of raising the bread be prolonged beyond usual limits. In addition to this, it must be considered that it is difficult in the process of baking to expel all the products of the fermentation. A portion of the carbon dioxid and of the alcohol will undoubtedly remain entangled in the meshes of the loaf. Even, therefore, allowing for the fact that a portion of the starch may be converted into sugar and undergo a partial fermentation, it is not to be expected that the total loss in weight in dry matter in the loaf itself will be greater than the amount of sugar originally present in the flour. Of course, it is understood if the loaf be ground and dried for the purpose of a chemical determination of loss that the whole of the alcohol and carbon dioxid will be driven off, but in the loaf as it comes from the oven or as it is brought upon the table such a complete evaporation of the volatile products of fermentation is not found. * * *

In addition to the many changes mentioned above as due to fermentation, certain changes in the constitution of the materials of flour are produced by the combined action of heat and water. These changes, of course, are produced in the maximum degree in the crust of the bread, whereas the temperature of boiling water in the interior of the bread acts less vigorously in its effects upon the chemical constituents of the flour. In respect to the proteid matters, it is certain that all of the proteids of the material will be rendered insoluble by the temperature to which they are subjected. The proteid matters in the crust of bread certainly undergo additional changes by reason of the high temperature to which they are subjected, the nature of which is not definitely known. The same is true of the fats or oils, which are oxidized to a certain extent by the action of the oxygen of the atmosphere at the high temperature to which the crust is subjected. It is probable, therefore, that a splitting up to some degree of the molecules of the glycerids composing the fat and oil takes place, especially in the crust of the loaf. In the interior of the loaf the carbohydrates probably undergo little change except a degradation of the starch grains and a slight tendency of the starch to be converted into dextrin. In the crust, however, in addition to those changes, there is a decided caramelization of the starchy particles, as is evidenced by the browning of the loaf.

Bakery experiments in 1895 and 1896.—In 1895 two experiments were conducted at a well-equipped bakery in New Brunswick[1] to study the relative cost of the nutrients in bread and in its raw materials, and also the changes which occur in converting the latter into the former. The results were unexpected. It was found in these experiments that not only was there little apparent loss of protein and of carbohydrates but that there was a considerable loss of ether extract. A similar experiment has recently been conducted by Miss Isabel Bevier, at Pittsburg, Pa., and with similar results.[2]

For convenience in comparison, the results of these experiments have been recalculated to a uniform basis of 100 grams of dry matter in the materials used, and are summarized in the following table:

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 52.

Summary of experiments in bread making at bakeries in New Brunswick and Pittsburg.

	Dry matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
First New Brunswick experiment:						
Material used	100.00	13.03	3.52	81.37	2.08	465.87
Material recovered	97.95	13.15	1.52	81.64	1.64	444.95
Material lost (—) or gained (+)	—2.05	+.12	—2.00	+.27	—.44	—20.92
Second New Brunswick experiment:						
Material used	100.00	13.74	4.01	80.16	2.09	457.90
Material recovered	97.04	13.72	1.64	79.78	1.90	443.73
Material lost	2.96	.02	2.37	.38	.19	14.17
Pittsburg experiment:						
Material used	100.00	15.58	1.35	80.87	2.20	435.64
Material recovered	95.88	15.37	.39	78.31	1.81	412.06
Material lost	4.12	.21	.96	2.56	.39	23.58

It will be seen from the above table that all of the ash was not recovered. This was undoubtedly due entirely to the method followed in making the ash determinations. There was practically no loss of nitrogenous materials, since the experiments show only variations which are within the limits of experimental error.

In the case of the fat the full amount supplied by the raw materials was not recovered in the ether extract of the bread, the discrepancy being greater, absolutely, and less, relatively, in the New Brunswick experiments than in that at Pittsburg. This is probably due to the fact that in the former case much more fat (lard) was used in making the dough than in the latter. The results from the two experiments differ, however, in one important particular. In the experiments at New Brunswick, the entire loss in total dry matter was accounted for by the losses in fat and ash; in that conducted at Pittsburg there was in addition a loss which by our methods of analysis falls upon the carbohydrates, since the carbohydrates are estimated by difference, and include the sums of the discrepancies. This amounted to 62 per cent of the entire loss. In all cases the fuel value (heat of combustion) of the bread was considerably less than that of the materials. In our belief this tended rather to verify than disprove that an actual loss of fat occurs in the process of baking, and that the loss is much greater than was formerly supposed. In Miss Bevier's opinion "it would seem that either the fat is rendered partially insoluble in ether during the process of baking or that it has been volatilized. The fact that there is a very considerable loss in the fuel value of the materials in the bread, as compared with that of the raw ingredients before baking, indicates that the latter is the true explanation, for, if the fats had simply been rendered nonextractable their heat of combustion would probably have remained nearly unchanged, and there would be no such pronounced loss of heat values as is actually the case."

Laboratory experiments in 1897.—In order to study further the changes which take place in the fat when bread is made, laboratory experiments[1] were conducted in 1897 upon small quantities and with a close control. The process of making bread may be divided into four steps, viz, (1) making the dough, (2) adding the leavening, (3) adding the shortening, and (4) the baking. In addition, in order properly to prepare the sample of bread for analysis, a subsequent drying is necessary. The experiments were so planned, therefore, that the bread making was arrested at the termination of the various steps and the resulting product analyzed. They show, therefore, the analysis of flour under the following conditions:

(1) Unmanipulated.

(2) Subjected to a temperature of 70° C., this being the temperature necessary to dry a sample of bread for analysis.

(3) Made into dough and then prepared for analysis by careful drying.

(4) Made into dough, baked unleavened, and then prepared for analysis as before.

(5) Made into dough, leavened, and then prepared for analysis.

(6) Made into dough, leavened and baked, and prepared for analysis.

(7) Made into dough, leavened and shortened, and prepared for analysis.

(8) Made into dough, leavened, shortened and baked, and prepared for analysis.

The results of these tests may be briefly summarized as follows: The amounts of dry matter in the samples prepared by these methods were but slightly different from the amounts which, on the basis of analyses, it was calculated the raw materials would furnish, the differences occurring mainly in the baked samples, probably on account of the browning of the crust. The amount of ether extract, however, was diminished in every case when the flour had been wet—i. e., made into a paste—the loss running as high as 85 per cent of the total fat. Simply drying the flour at 70° C. did not affect the amount of ether extract seriously. In the case of the samples to which milk (shortening) had been added, the total ether extract recovered was less than was added in the milk alone, although it is generally assumed that milk fat is not affected by a temperature of 100° C. There was no uniform connection observed between the apparent loss of the fat (ether extract) or loss of dry matter and the deficiency in heat of combustion; and in no case where the apparent loss of fat was serious was the deficiency in fuel value sufficient to account for the apparent loss in fat.

The fact that practically all the dry matter was recovered would indicate that the fat was not lost, but was unextracted. It is well understood that in the case of linseed meal, corn meal, and other similar products protracted heating in air will hinder the extraction of fat. This is usually attributed to oxidation, and it is known that oxidation certainly takes place when an air-dry sample of such material is heated. As noted above, protracted heating of the air-dry flour at 70° C. had only a trifling effect upon the ether extract. This fact and the failure to recover all the milk fat suggested that it was not oxidation but occlusion which hindered the ether from exerting its solvent action. In this particular the conclusions drawn from the experiments at the bakeries seem to be contradicted by the laboratory experiments.

---

[1] New Jersey Stas. Rpt. 1897, p. 98.

LOSS OF MATERIAL IN BREAD MAKING.

EXPERIMENTS IN 1898—METHODS FOLLOWED.

Further experiments along these lines were conducted during 1898 to test the results previously secured and to extend the investigations. The brand of flour selected was the same as that used in 1897. Twenty-five pounds was carefully mixed and distributed in 25 glass jars by transferring a large spoonful to each jar, thoroughly mixing the remainder, and again transferring a spoonful to each jar. This was repeated until all but about a pound had been placed in the jars. This small remainder was discarded. The jars were closed with perfectly fitting tops and new rubber rings. A composite sample for proximate analysis was made up of portions from jars 1, 6, 10, 15, 19, and 24, and in addition, to test the uniformity of the distribution, determinations of moisture, protein, ether extract, and ash were made in the contents of jars 3, 8, 12, and 21. The results were all very uniform, the composite sample being practically identical with the average of the others, as is shown by the following table:

Composition of samples of flour.

	Water.	Nitrogen.	Ether extract.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sample from jar 3	12.21	2.22	1.25	0.49
Sample from jar 8	12.19	2.25	1.24	.52
Sample from jar 12	12.20	2.20	1.25	.50
Sample from jar 21	12.20	2.20	1.31	.53
Average	12.20	2.22	1.26	.51
Composite sample from jars 1, 6, 10, 15, 19, and 24	12.20	2.22	1.27	.51

In order to avoid the complications which would ensue from fermentation due to the use of yeast, the leavening in the bread-making experiments was accomplished, as in the experiments in 1897, with a leavening powder, a mixture of sodium bicarbonate and potash alum being used. The moisture, ether extract, and nitrogen in these substances were determined, and also in the combination of the two after they had been wet and the reaction had taken place. They contained neither nitrogen nor ether soluble substance. The dry matter was also determined. Since this consisted of sodium and potassium sulphates and aluminum hydrate, and as no salt (NaCl) was added in making the bread or the mixtures, it was considered sufficiently accurate to assume the ash by calculation.

EFFECT OF HEAT ON MILK.

In making bread, milk was used to furnish fat, since it is believed milk fat is not sufficiently affected when exposed to the air at temperatures not exceeding 100° C. to be rendered nonextractable with ether. In order to verify this belief, portions of milk weighing 25 grams each were dried upon pumice stone in three ways: (1) in an air bath at 70° C, (2) in a water oven at about 100° in air, and (3) in a water oven at about 100° in a current of dry hydrogen. The dried samples were analyzed. The results of these analyses are shown in the following table, together with the calculated constituents of 25 grams of milk before drying:

Constituents of fresh milk and milk dried in various ways.

	Solids.	Ether extract.	Casein.
	Grams.	*Gram.*	*Gram.*
Milk (25 grams), fresh (calculated)	3.05	0.91	0.81
Milk (25 grams), dried at 70° C.	2.93	.89	.83
Milk (25 grams), dried at 100° C.	2.98	.89	.84
Milk (25 grams), dried at 100° C. in hydrogen	2.94	.90	.84

It will be seen that the milk, and especially its fat content, was not affected by the temperatures used in drying the samples or by the temperature which is generally assumed[1] to be that of the interior of the loaf during baking.

TESTS WITH BREAD MADE IN VARIOUS WAYS.

In making the bread care was taken to prevent any burning or indeed any undue browning of the crust during baking, and it is believed that the problem studied is not complicated by any loss from such a cause. The portions of flour and milk used in making the bread and the resulting products were weighed on a large balance, sensitive to 10 milligrams, while the leavening chemicals, on account of their small amount, were weighed on an analytical balance, sensitive to one-twentieth milligram. After the raw materials were weighed extreme care was taken to prevent accession or loss of moisture. Rubber stoppers were substituted for the glass stoppers of the sample bottles, as changes in moisture content have been detected in the past in fodder materials contained in bottles stoppered with glass. The weight of the samples analyzed was also determined before and after grinding. Only slight variations were observed. They were undoubtedly those incidental to grinding and sifting the samples, etc.

---

[1] See Wiley, "Principles and Practice of Agricultural Analysis," Vol. III, p. 543; see also quotations from Blyth at beginning of this article.

For each experiment 100 grams of flour was used; the flour was submitted to the same manipulation as in the experiments made in 1897 (see p. 40). In addition in some of the experiments a water oven was used for drying the product obtained at various steps in the bread-making process. In some instances the materials were dried in an atmosphere of hydrogen in a water oven at 100°. In all cases the samples were dried in air unless hydrogen is specified. The analysis of the raw materials and the various products were made by the methods prescribed by the Association of Official Agricultural Chemists.[1] Since the ether extract is determined in the sample which is used for the determination of dry matter, those samples which were dried in air or in hydrogen were in reality submitted to two dryings—one previous to analysis and one during analysis.

The results of the tests are given in the following table, which shows the composition of the unmanipulated flour or flour and other raw materials and their composition after treatment in the various ways indicated:

Constituents of materials and bread made in various ways.

Experiment number.		Dry matter.	In dry matter.			
			Protein.	Ether extract.	Carbohydrates.	Ash.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
	Bread made from flour and water only:					
1	Flour, unmanipulated (100 grams)	87.80	13.88	1.27	72.14	0.51
2	Flour dried in air at 70° C	87.45	13.88	1.27	71.79	.51
3	Flour dried in air at 100° C	87.59	13.69	.84	72.55	.51
4	Flour made into dough and dried in air at 70° C.	87.98	13.44	.63	73.40	.51
5	Bread baked and dried at 70° C	87.54	13.56	.28	73.19	.51
6	Bread baked and dried at 100° C	87.82	13.93	.38	73.00	.51
	Bread made with flour, leavening, and water:					
	Flour (100 grams)	87.80	13.88	1.27	72.14	.51
	Leavening chemicals (1.56 grams)	1.56				1.56
	Total (calculated)	89.36	13.88	1.27	72.14	2.07
7	Total by analysis	89.39	13.88	1.33	72.11	2.07
8	Materials dried in air at 70° C	89.71	13.56	1.23	72.85	2.07
9	Materials dried in air at 100° C	89.41	13.75	.55	73.04	2.07
10	Materials made into dough and dried in air at 70° C.	89.17	13.56	.47	73.07	2.07
11	Dough dried in air at 100° C	89.37	13.81	.48	73.01	2.07
12	Dough dried in hydrogen at 100° C	89.04	13.56	.32	73.09	2.07
13		89.01	13.63	.31	73.00	2.07
14	Bread baked and dried at 70° C	89.38	13.81	.29	73.21	2.07
15		89.76	13.44	.39	73.86	2.07
16	Bread baked and dried at 100° C	89.24	13.81	.31	73.05	2.07
17		89.38	13.44	.23	73.64	2.07
18	Bread baked and dried in hydrogen	88.82	13.50	.29	72.96	2.07
	Bread made with flour, leavening, and milk:					
	Flour (100 grams)	87.80	13.88	1.27		
	Milk (104 grams)	12.70	3.32	3.73		
	Leavening chemicals	3.12				
	Total	103.62	17.20	5.00		

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46.

Constituents of materials and bread made in various ways—Continued.

Experiment number.		Dry matter.	In dry matter.			
			Protein.	Ether extract.	Carbohydrates.	Ash.
	Bread made with flour, leavening, and milk—Cont'd.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
19	Dough dried in air at 70° C	103.67	17.06	3.95	......	......
20	Dough dried in air at 100° C	103.87	16.81	3.42	......	......
21	Dough dried in hydrogen	102.59	17.00	2.76	......	......
22	Bread baked and dried at 70° C	103.33	16.94	3.17	......	......
23	Bread baked and dried in hydrogen	101.92	16.88	2.49	......	......
	Bread made with flour previously extracted with ether:					
	Flour (100 grams)	93.31	14.56	.11	......	......
	Milk (104 grams)	12.70	3.32	3.73	......	......
	Leavening chemicals	3.12	......	......	......	......
	Total	109.13	17.88	3.84	......	......
24	Dough dried in air at 70° C	109.42	17.88	3.23	......	......
25	Dough dried in air at 100° C	109 35	18.00	2.76	......	......
26	Dough dried in hydrogen	109.17	17.88	2.26	......	......
27	Bread baked and dried at 70° C	109.59	18.00	2.09	......	......
28	Bread baked and dried in hydrogen	108.42	18.00	2.22	......	......

In all the experiments it will be noticed that the loss of nitrogenous constituents was very small, the greatest variation being equivalent to a variation of about 0.1 per cent of nitrogen. This is within the limits of experimental error and confirms the conclusions from the bakery experiments previously reported. In the case of the carbohydrates also there were no apparent losses. Such losses were not expected, since yeast was not employed to leaven the bread. On the contrary, in almost every case there was an apparent gain, but, as the carbohydrates are determined by difference and include the sum of all the errors in the determinations of the other constituents, these gains are not necessarily significant. They are intimately related to variations in the dry matter and ether extract. The results with these constituents confirm previous work. Practically all the dry matter was recovered in almost every case, but in those experiments (Nos. 1–18), in which no fat was present except that supplied by the flour, the ether extract showed deficiencies when either a high temperature was employed to dry the raw material or when the materials had been wet in making into dough. These discrepancies ranged from 33 to 70 per cent of the total ether extract. In experiments Nos. 19–23, in which milk fat had been added in making the bread, the ether extract recovered in but one instance equaled the amount supplied in the milk alone. The apparent loss of fat, therefore, holds good for the animal fat added to the dough as well as to the vegetable fat present in the flour. This is well shown in experiments Nos. 24–28, which were made with flour which had been previously extracted with ether until practically free from fat. In these experiments also the added animal fat was not entirely recovered.

The following explanations have been suggested for this discrepancy in fat: (1) Oxidation, which prevents the extraction of the fat, causing it to be estimated with the carbohydrates; (2) volatilization, whereby the fat is actually lost, and (3) occlusion, with a result similar to oxidation.

Oxidation.—As has already been stated, it is well known that vegetable substances containing drying oils, such as linseed meal and corn meal, can not properly be dried, for analysis, in air previous to extraction with ether, for the fat will be oxidized and rendered partially insoluble. The water also can not be determined by drying in air, for the results will be too low or, what is the same thing, the dry matter, will be too high. These considerations lead to the method of drying samples in an atmosphere of hydrogen. If there is an oxidation of fat there should also be an increase in the dry matter recovered. As is shown in the experiments, there was in most cases very little gain in the dry matter, and in experiments Nos. 12, 13, 18, 21, 23, 26, and 28, where the materials were dried in hydrogen and the dry matter recovered was actually lower than when dried in air, there is as great a discrepancy in the fat as when the samples were dried in air. This indicates that a change of some sort has taken place, but the lower results secured do not necessarily indicate that the change has taken place in the fat. Furthermore, there is a loss of milk fat, which in some cases is considerable, notably in the samples which were dried in hydrogen. Judging by the experiments in which milk was dried on pumice stone, this loss would not be expected.

Volatilization.—If the fat had been volatilized, there should be a corresponding loss of dry matter and this would be observed equally in the samples dried in hydrogen and in those dried in air. That there is no loss of dry matter in the majority of cases would seem to rule out the possibility of volatilization unless, indeed, it were accompanied by a compensating oxidation. This hypothesis would fulfill the conditions at present shown to exist, since, when the samples were dried in hydrogen, there was a loss of fat and dry matter; when dried in air there was a loss of fat and no loss of dry matter. Furthermore, in the samples in which there was no vegetable fat to be volatilized, i. e., those in which extracted flour was used, there was a gain of dry matter when dried in air and none when dried in hydrogen.

Occlusion.—Occlusion was suggested by our work of last year, when the dry matter was recovered in almost every case. Occlusion would insure the fat being estimated as carbohydrates without alteration in the amounts of dry matter.

TESTS WITH FLOUR FROM WHICH THE GLIADIN WAS EXTRACTED.

Experiments were therefore undertaken similar to those reported by Snyder (see p. 23) to try the effect of making bread with flour from which the gliadin or plant gelatin had been extracted, since this is the material which binds the flour particles together to form a dough, and when dried might be reasonably expected to cause occlusion. A portion of the same flour used in the previous experiments was digested repeatedly with alcohol and finally with ether. With the flour thus prepared experiments similar to those with the untreated flour were made: (1) The ingredients of bread were mixed and dried without further manipulation. (2) The ingredients were mixed and made into bread, chemicals being used for leavening. (3) Bread was made from the same ingredients with the addition of milk. The results obtained from the analysis of the materials and the resulting products are shown in the following table:

Results of experiments with flour from which the gliadin was extracted.

Experiment No.		Dry matter.	In dry matter.	
			Protein.	Ether extract.
	Flour (100 grams) extracted with alcohol:	*Grams.*	*Grams.*	*Grams.*
29	Flour undried	86.70	7.44	0.44
30	Flour dried in air at 70° C	87.49	7.31	.39
31	Flour dried in air at 100° C	87.86	7.31	.32
	Bread made from flour (100 grams) extracted with alcohol:			
	Flour	86.70	7.44	.44
	Leavening chemicals	3.12		
	Total	89.82	7.44	.44
32	Flour made into dough and dried at 70° C	91.15	7.31	.18
33	Dough dried in air at 100° C	90.75	7.38	.09
34	Dough dried in hydrogen at 100° C	89.22	7.63	.07
35	Bread baked and dried at 70° C	88.00	7.25	.06
36	Bread baked and dried in hydrogen at 100° C	88.71	7.50	.06
	Bread made with extracted flour and milk:			
	Flour extracted with alcohol (100 grams)	86.70	7.44	.44
	Milk (104 grams)	12.70	3.32	3.73
	Leavening chemicals	3.12		
	Total	102.52	10.76	4.17
37	Flour made into dough and dried in air at 70° C	103.07	10.63	3.46
38	Dough dried in air at 100° C	103.27	10.50	2.81
39	Dough dried in hydrogen	102.52	10.63	1.95
40	Bread baked and dried at 70° C	103.03	10.44	2.28
41	Bread baked and dried in hydrogen at 100° C	103.32	10.69	2.31

It was found that the dough made from the extracted flour was like that described by Snyder (see p. 23). It was not sticky and resembled putty in feeling and appearance. The leavening employed caused the mass to expand a little when first placed in the oven; then the top of the loaf began to break apart, and the loaf decreased in size as if no leavening had been used. The loaf when baked was about as heavy as the same bulk of rubber. The results of the experiments show that the fat was not recovered, even when gliadin was absent; that is, removing the gliadin, i. e., the material which it might be assumed would cause an occlusion of fat, did not prevent an apparent loss of fat in bread making.

COMPARISON OF DIFFERENT METHODS OF EXTRACTING FAT.

Several years ago Weibull[1] studied the determination of the fat in bread. He found that bread apparently contained less fat than the flour from which it was made. This he attributed to an error of analysis, since direct extraction with ether gave too low results in the case of bread, no matter how long the extraction was continued. The starch and dextrin of the bread were thought to inclose the fat and prevent the action of the ether. To obviate this difficulty the author proceeded as follows:

---

[1] Svensk Kemisk Tidskrift, 1892, No. 5 (Experiment Station Record, 5, p. 520).

From 1 to 3 grams of dry pulverized bread was boiled for an hour with 15 to 20 cubic centimeters of water and 10 drops of dilute H_2SO_4, being stirred occasionally with a glass rod. The solution was then completely neutralized with an excess of calcium carbonate (powdered marble) containing no ether extract and the thick solution transferred to a piece of fat-free filter paper, such as is used in milk analysis, the beaker which had contained the solution being wiped out with absorbent cotton. The paper and cotton were heated at 100° C. for two or three hours, and then extracted in an extraction apparatus with anhydrous ether for ten hours. Parallel determinations by this method agreed perfectly, and comparative analyses of fat in flour and in the bread made from the same according to the author gave concordant results; that is, when a method was employed which prevented the occlusion of the fat it was all recovered.

In view of these results a few samples of flour and bread were treated according to Weibull's method. The results are given in the following table. For purposes of comparison the results obtained by the usual method, and also by direct extraction of the undried substance, are also included since it has been suggested that, when the official method is employed, the preliminary drying still further hardens the particles and increases the occlusion. The results in every case have been calculated to show the grams of fat in 100 grams of flour or the bread made from this quantity.

Comparison of different methods of estimating fat in flour and bread.

Experiment No.		Weibull's method.	Official method.	Direct extraction.[1]
		Grams.	*Grams.*	*Grams.*
1	Flour undried	1.06	1.27	1.44
2	Flour dried in air at 70° C	1.01	1.27	1.30
3	Flour dried in air at 100° C	.71	.84	.94
4	Flour made into dough and dried in air at 70° C	.69	.63	.66
5	Bread baked and dried at 70° C	.66	.28	.37
19	Bread[2] dried in air at 70° C	3.81	3.95	3.73
20	Bread[2] dried in air at 100° C	3.88	3.42	3.73
21	Bread[2] dried in hydrogen	3.82	2.76	3.73

[1] Without further drying of the substance.

[2] Made with milk.

Weibull's method gave fairly concordant results, but they were on the whole not as satisfactory as his statements would seem to indicate might be expected.

An examination of the above figures shows no gain in ether extract in the results of experiments with the flour alone. In those cases in which milk was added to the flour in making bread, an amount of fat equal to all the milk fat and a very little more was recovered by Weibull's method, which would indicate that not only was a little of the vegetable fat occluded, but considerable amounts of the animal fat also. This would be more in accord with the results secured from the experiments with milk dried on pumice than would the supposition that oxidation had taken place.

These results and those previously reported (pp. 43, 44) represent experiments on the loss of fat in materials which were heated and, with the exception of the few samples dried, as received, at 100° C. in air, the loss in materials which were wet or made into a dough and dried.

COMPARISON OF EXPERIMENTAL METHODS.

In order to learn how much of the effects were due to heat, a number of tests were made in which the dough was not heated in drying. Portions of flour were made into dough with an abundance of the leavening chemicals to facilitate drying, rolled out thin on plates, and dried at room temperature under bell jars over concentrated sulphuric acid. Two tests were made, the same quantities of flour and leavening materials being used in each case. When analyzed by the official methods the dry matter was found to be lower than the calculated amount, and the ether extract also showed a deficiency as in the previous experiments. The results of the two tests were as follows:

Constituents of materials and dried dough made from them.

Experiment No.		Dry matter.	In dry matter.			
			Protein.	Ether extract.	Carbohydrates.	Ash.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
	Flour (100 grams)	87.80	13.88	1.27	72.14	0.51
	Leavening chemicals	6.24				6.24
	Total	94.04	13.88	1.27	72.14	6.75
42	Dried dough	93.08	13.90	.80	71.63	6.75
43	....do	92.72	13.46	.67	71.84	6.75

It will be seen that even in these cases there was a loss of ether extract and dry matter. It should be remembered, however, that even in this instance the determination of dry matter involves drying (in hydrogen) and that the ether extract was regularly determined in this dried portion. Therefore other portions of the flour and dried dough were extracted without previous drying. The results showed but a trifling gain. These experiments, however, showed what is regarded as the cause of the loss of fat, for when the ether extract was dried preparatory to weighing, copious white acrid fumes issued from the flask and constant weight was with difficulty secured. These fumes were not noticed in drying the extract from the substance previously dried, and only slight amounts were noticed in the tests reported on page 47. This would indicate that when samples are analyzed in the ordinary way, the volatilization of a portion of the ether extract probably takes place in drying the sample for analysis, and doubtless also occurs whenever the sample is dried or baked. If this is the case, the samples prepared in the early experiments should show a loss of substance, and if this is compensated by a corresponding oxidation it should be possible to detect the loss by means of the calorimeter. On the other hand, in experiments Nos. 42 and 43 the heat of combustion of the substance as it comes from the desiccator should be the same as that of the material before drying; i. e., there should be no loss in energy, the analytical results to the contrary notwithstanding. Such determinations were made, therefore, upon these samples (Nos. 42 and 43), and a number of others and the results obtained, together with the amounts of dry matter and ether extract in the samples, are given in the following table:

Dry matter, ether extract, and heat of combustion of flour and bread treated in various ways.

Experiment No.		Dry matter.	Ether extract in dry matter.	Heat of combustion.
	Unextracted flour (100 grams).			
		Grams.	*Grams.*	*Calories.*
	Mixture of flour (100 grams) and leavening chemicals (1.56 grams)	89. 36	1. 27	387. 37
8	Same mixture dried in air at 70° C	89. 71	1. 23	377. 07
9	Same mixture dried in air at 100° C	89. 41	. 55	378. 08
12	Dough dried in hydrogen	89. 04	. 32	381. 85
13	.....do	89. 01	. 31	380. 79
	Mixture of flour dried in desiccator and leavening chemicals (6.24 grams)	94. 04	1. 27	387. 37
42	Dough from same	93. 08	. 80	389. 61
43	.....do	92. 72	. 67	387. 27
	Flour extracted with alcohol (100 grams).			
29	Flour undried	86. 70	. 44	371. 63
30	Flour dried in air at 70° C	87. 49	. 39	367. 80
31	Flour dried in air at 100° C	87. 86	. 32	366. 65
	Mixture of flour (100 grams) and leavening chemicals (3.12 grams)	89. 82	. 44	371. 63
34	Dough from same dried in hydrogen	89. 22	. 07	371. 15

Although these results were obtained from a limited number of samples, they have been made in duplicate and in some cases in triplicate and were found to be concordant, indicating that they are trustworthy. They show exactly that which was expected from the preceding work. The material dried over sulphuric acid has lost none of its potential energy and, therefore, presumably none of its substance previous to drying in hydrogen; the whole flour when dried in hydrogen lost both potential energy and substance, which, since the possibility of oxidation was excluded, must be due to volatilization; when dried in air the material lost still more fuel value, but showed no loss of substance. Both of these facts can be explained by absorption of oxygen, i. e., slow combustion or oxidation. When the material contained no vegetable fat to volatilize, there was no loss of substance or of energy when dried in hydrogen. Furthermore, there was a gain of weight and loss of energy when dried in air.

CONCLUSIONS.

From these results it seems proper to conclude that at high temperatures there is a partial volatilization of the vegetable fat in bread making, especially in the presence of escaping water vapor, and, in addition, an oxidation of the residual organic matter. When animal fat was added to the dough there seemed to be an occlusion of fat, probably due to the formation of dextrin. The application of this theory to the results of the bakery experiments previously referred to explains the facts noted, namely, that—

(1) Although yeast was used in all the bakery experiments and the destruction of carbohydrates must have been considerable, yet the experiments at New Brunswick, unlike that at Pittsburg, show no apparent loss of carbohydrates.

(2) The fuel value when calculated by the usual factors[1] was less than the value obtained by actual determinations in the second New Brunswick experiment, while this was not the case in the experiment made at Pittsburg.

(3) The loss of fat in the New Brunswick experiments, when animal fat (in milk) was added in making the bread, was proportionately less than in the Pittsburg experiment.

The loss of carbohydrates is partly covered in the Pittsburg experiment, where no animal fat was used, by an oxidation of organic matter, and in the New Brunswick experiment, where animal fat was used, by oxidation of the same character, together with an occlusion of some of this animal fat. By the usual methods of analysis this would be calculated as carbohydrates. Therefore, in the application of estimated fuel values to the lost nutrients in the New Brunswick experiment 9.3 calories per gram is too large a value for loss of fat, since a portion of the fat is not lost, but is occluded and thereby estimated as carbohydrates. On the other hand, 4.1 calories per gram (the value for carbohydrates) is too small, since the entire amount of fat is not occluded, there being some absolute loss of fat and in addition a partial oxidation of organic matter. The carbohydrates so called, thus gain in weight but lose fuel value. In the Pittsburg experiment no animal fat was used in making the bread. If it be assumed that no occlusion of fat took place, the use of the customary factors in calculating the fuel values would give a result a trifle too small, on account of the slow oxidation referred to. This was in accord with the observed facts.

---

[1] On the supposition that 1 gram of protein, fat, and carbohydrates will yield 5.5, 9.3, and 4.1 calories, respectively, in the estimation of fuel values as distinguished from heats of combustion the factor 4.1 per gram is commonly used for protein compounds, thus allowing for their incomplete oxidation in the body.

The factors for determining the fuel value of cereals and cereal products have been recently investigated by the Division of Chemistry of this Department (U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, p. 1243). On the basis of determinations of the heat of combustion of the different constituents of cereals (with the exception of proteids) factors are proposed which differ somewhat from those mentioned above.

From the investigations reported in this bulletin it is evident that some of the apparent loss of ether extract in bread making was due to heat employed in baking the bread and to the heat employed in drying the samples for analysis.

When samples of flour, dough, and bread were dried in air or in hydrogen previous to analysis, an apparent loss of ether extract was observed. It should be remembered, however, that since ether extract is usually determined in a sample used for determination of dry matter, the materials have been subjected to two dryings, one previous to analysis and one during analysis. When samples of flour and dough dried over sulphuric acid were analyzed there was also an apparent loss of fat. The loss was, however, smaller than was the case when samples dried in air or hydrogen were analyzed. In this case the samples had been submitted to the action of heat but once; that is, in the determination of dry matter in the sample before extracting with ether. Samples of dough dried over sulphuric acid were extracted with ether without any further drying; that is, without submitting them to the action of heat. In this case slightly more ether extract was recovered than when similar samples were extracted after drying in an oven for the determination of dry matter. In all these cases, however, there was an apparent loss of ether extract; that is, when flour is made into dough and dried or baked, all the ether extract of the flour can not be recovered. It would appear from the data reported that the losses which have been observed in previous investigations at New Brunswick and Pittsburg were more largely due to the analytical methods, that is, to the drying to which the samples were submitted than to the action of the heat in baking. This is not surprising, since baking the bread occupied but twenty or thirty minutes, while the drying for analysis required five or six hours; furthermore, the temperature of the bulk of the loaf during baking was not greater than that of the sample when dried in hydrogen. There was more of the pleasant odor of bread making when the samples were drying than when they were baking. In all cases when the drying was made in hydrogen the sulphuric acid in the trap at the exit of the hydrogen current became black, indicating that some volatile compound was absorbed by it and oxidized. The results obtained indicate that less oxidation of fat takes place at 70° than at 100°, therefore the former temperature is to be preferred in drying organic materials for the estimation of dry matter.

These considerations indicate that the usual custom of drying fodder and food samples in air or in hydrogen in a drying oven previous to extraction with ether should be carefully investigated in view of the possible errors in the estimation of ether extract involved.

○

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN.[1]

Charts. Food and Diet. By W. O. Atwater. (Four charts, 26 by 40 inches.) Price per set, unmounted, 75 cents.

Bul. 21. Methods and Results of Investigations on the Chemistry and Economy of Food. By W. O. Atwater. Pp. 222. Price, 15 cents.

Bul. 28. (Revised edition. The Chemical Composition of American Food Materials. By W. O. Atwater and A. P. Bryant. Pp. 87. Price, 5 cents.

Bul. 29. Dietary Studies at the University of Tennessee in 1895. By C. E. Wait, with comments by W. O. Atwater and C. D. Woods. Pp. 45. Price, 5 cents.

Bul. 31. Dietary Studies at the University of Missouri in 1895, and Data Relating to Bread and Meat Consumption in Missouri. By H. B. Gibson, S. Calvert, and D. W. May, with comments by W. O. Atwater and C. D. Woods. Pp. 24. Price, 5 cents.

Bul. 32. Dietary Studies at Purdue University, Lafayette, Ind., in 1895. By W. E. Stone, with comments by W. O. Atwater and C. D. Woods. Pp. 28. Price, 5 cents.

Bul. 35. Food and Nutrition Investigations in New Jersey in 1895 and 1896. By E. B. Voorhees. Pp. 40. Price, 5 cents.

Bul. 37. Dietary Studies at the Maine State College in 1895. By W. H. Jordan. Pp. 57. Price, 5 cents.

Bul. 38. Dietary Studies with Reference to the Food of the Negro in Alabama in 1895 and 1896. Conducted with the Cooperation of the Tuskegee Normal and Industrial Institute and the Agricultural and Mechanical College of Alabama. Reported by W. O. Atwater and C. D. Woods. Pp. 69. Price, 5 cents.

Bul. 40. Dietary Studies in New Mexico in 1895. By A. Goss. Pp. 23. Price, 5 cents.

Bul. 43. Losses in Boiling Vegetables and the Composition and Digestibility of Potatoes and Eggs. By H. Snyder, A. J. Frisby, and A. P. Bryant. Pp. 31. Price, 5 cents.

Bul. 44. Report of Preliminary Investigations on the Metabolism of Nitrogen and Carbon in the Human Organism with a Respiration Calorimeter of Special Construction. By W. O. Atwater, C. D. Woods, and F. G. Benedict. Pp. 64. Price, 5 cents.

Bul. 45. A Digest of Metabolism Experiments in which the Balance of Income and Outgo was Determined. By W. O. Atwater and C. F. Langworthy. Pp. 434. Price, 25 cents.

Bul. 46. Dietary Studies in New York City in 1895 and 1896. By W. O. Atwater and C. D. Woods. Pp. 117. Price, 10 cents.

Bul. 52. Nutrition Investigations in Pittsburg, Pa., 1894-1896. By Isabel Bevier. Pp. 48. Price, 5 cents.

Bul. 53. Nutrition Investigations at the University of Tennessee in 1896 and 1897. By C. E. Wait. Pp. 46. Price, 5 cents.

Bul. 54. Nutrition Investigations in New Mexico in 1897. By A. Goss. Pp. 20. Price, 5 cents.

Bul. 55. Dietary Studies in Chicago in 1895 and 1896. Conducted with the Cooperation of Jane Addams and Caroline L. Hunt, of Hull House. Reported by W. O. Atwater and A. P. Bryant. Pp. 76. Price, 5 cents.

Bul. 56. History and Present Status of Instruction in Cooking in the Public Schools of New York City. Reported by Mrs. Louise E. Hogan, with an introduction by A. C. True, Ph. D. Pp. 70. Price, 5 cents.

Bul. 63. Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body. By W. O. Atwater and E. B. Rosa. Pp. 94. Price, 10 cents.

Bul. 66. The Physiological Effect of Creatin and Creatinin and their Value as Nutrients. By J. W. Mallet. Pp. 24. Price, 5 cents.

Bul. 67. Studies on Bread and Bread Making. By Harry Snyder and L. A. Voorhees. Pp. 51. Price, 5 cents.

FARMERS' BULLETINS.

Bul. 23. Foods: Nutritive Value and Cost. By W. O. Atwater. Pp. 32.

Bul. 34. Meats: Composition and Cooking. By C. D. Woods. Pp. 29.

Bul. 74. Milk as Food. Pp. 39.

Bul. 85. Fish as Food. By C. F. Langworthy. Pp. 30.

Bul. 93. Sugar as Food. By Mary H. Abel. Pp. 27.

---

[1] For those publications to which a price is affixed application should be made to the Superintendent of Documents, Union Building, Washington, D. C., the officer designated by law to sell Government publications.

BULLETIN No. 68.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS.
A. C. TRUE, Director.

A DESCRIPTION
OF
SOME CHINESE VEGETABLE FOOD MATERIALS
AND
THEIR NUTRITIVE AND ECONOMIC VALUE

BY

WALTER C. BLASDALE,
Instructor in Chemistry, University of California.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1899.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., July 15, 1899.

Sir: I have the honor to transmit herewith a report by Walter C. Blasdale, instructor in chemistry at the University of California, describing some Chinese vegetable food materials and their nutritive and economic value.

These foods are used to a considerable extent by the Chinese population in San Francisco and other cities in the United States, and most, if not all, of them are staple articles of diet in China and the Orient. It seems probable that some of the vegetables may become generally and favorably known in the United States.

Very little information has been hitherto available concerning many of these materials, and it is believed the report is a useful contribution to the knowledge of the food of mankind.

The report is respectfully submitted, with the recommendation that it be published as Bulletin No. 68 of this Office.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
Introduction 5
Experimental methods 6
Roots and tubers 8
    Sagittaria, or arrowhead 8
    Taro 13
    Water chestnut 15
    Sacred lotus 17
    Lily bulbs 19
    Chinese sweet potatoes 22
    Yam bean 23
    Cassava, or manioc 25
Green vegetables and cucurbits 27
    Green vegetables 27
    Cucurbits 30
Seeds and grains 32
    Soy beans 32
    Phaseolus 36
    Dolichos 37
    Various water plants 39
    Chinese millet 41
Fruits, nuts, and flowers 42
Fungi and algæ 45
Miscellaneous substances 47

ILLUSTRATIONS.

Page.

PLATE I. Plant from an imported tuber of *Sagittaria sinensis* 8

II. Drawings of roots, seeds, etc 10

III. Drawings of starch grains.. 12

IV. Drawings of various roots 14

V. Plant from a corm of *Eleocharis tuberosa*.... 16

VI. Upper portion of a plant of the black soy bean.................... 32

VII. Mature plant of yellow soy bean 34

VIII. Plant of *Phaseolus mungo* 36

SOME CHINESE VEGETABLE FOOD MATERIALS.

INTRODUCTION.

A visit to the Chinese quarter of San Francisco or any of the larger Pacific Coast cities will reveal to the eyes of a nonresident much that is both strange and interesting. Most of the curious roots, green vegetables, seeds, and other articles of food making up the stock in trade of the Chinese merchant would be totally unknown and unsalable outside of the narrow limits of the Chinese quarter. These articles are for the most part of Asiatic origin, many of them being directly imported from Canton, while others, though grown on American soil, are distinctly Asiatic in character. Their presence here can be accounted for only on the supposition that they are of considerable importance in the domestic life of the Chinese. Evidently they are the equivalent of the materials that make up our own vegetable dietary and presumably possess an intrinsic value for such a purpose. The thought then naturally arises, Might not some of these materials be turned to good account in the American household?

Tradition assigns to the Chinese the highest attainment in the art of producing from a given area the greatest amount of food material. The latter result has been reached both by intensive cultivation and by the utilization of a great variety of food plants, so that all classes of soil and climate are made to yield their quota of food. It would not be unreasonable to suppose, therefore, that the little-known regions of the Chinese Empire from which we have already obtained many useful plants might yield still others of real economic value. It can not be taken for granted, however, that all such materials, even though they do form an important part of the Chinese dietary, would be desirable introductions into our own. Of the numerous factors which must be considered in determining this question the composition of the vegetables themselves is the most important. The amount of nutrients which they contain may be readily determined by submitting them to a chemical investigation. Such questions as digestibility, adaptation to American tastes, means of utilization, and cultural features of the plants themselves are all important elements in the problem.

Powerful incentives which might induce one to look for new varieties of food plants are not lacking. An increase in the number of vegetables which are in cultivation might admit of the utilization of a greater diversity of soil and climate, or of a more profitable use of the regions already in cultivation, or again might be desirable from a strictly dietetic standpoint.

It has long been accepted as true that the Chinese are largely vegetarian in their diet, and this apparently without serious detriment to their physical development. This statement, however, is not based on accurately compiled data, and, even if true, would be of no special significance until we know more about the composition of the Chinese vegetables. Apparently few analyses of Chinese food materials have been published, though Kellner, Nagai, Murai, and others have published a large number of analyses of Japanese food stuffs, many of which are produced by plants in common use among the Chinese. The incomplete character of some of these analyses and indeed of many others is likely to lead to erroneous conclusions. It is especially desirable to discriminate between crude protein and digestible nitrogenous compounds when dealing with vegetable substances, since often as much as two-thirds of the total nitrogen content consists of amido[1] compounds or other substances of little or no nutritive value.

EXPERIMENTAL METHODS.

It was through the consideration of such facts as the above that the work described in this article was undertaken. It has been confined to a study of the most important of the vegetable food materials found in the Chinese markets of San Francisco, though many substances of animal origin found there might profitably be submitted to similar investigation.

The work naturally divides itself into two distinct lines of research: First, the botanical and horticultural features of the materials studied, and, second, the extent to which these materials are used, the method of preparing and serving them, and the food value as shown by their chemical composition.

As a starting point for both lines of work it was necessary in each case to identify the plant from which the product under investigation was derived.[2] The identification proved in some instances a more difficult matter than might have been anticipated, for, though many notes on the economic plants of China are available, a large number of them contain conflicting statements and several different Chinese characters are often used to designate the same plant. In those instances in which the plants themselves could be grown by the author little difficulty was experienced, but this was in some instances an impossibility. As an assistance in this part of the work and also for the benefit of future workers in the same field, the name and Chinese character for each article were obtained when purchased, and these have been recorded in the body of the report. It is to be noted, however, that the names used in San Francisco are all in the Cantonese dialect, and both names and characters often represent commercial designations rather than the terms used in Chinese literature. In many instances the literary or classical terms have been added. Often the names obtained from the Chinese merchants gave but an uncertain clew to the name of the plant producing the article, and frequently different names were used for the same article. Aside from names and characters it was very difficult, either from their actual ignorance or lack of interest in the subject, to obtain authentic information from the Chinese consulted by the authorities in San Francisco regarding the source and method of use of many of the substances examined.

---

[1] In confirmation of this statement see Böhmer, Landw. Vers. Stat., 28 (1883), p. 247.

[2] An especial acknowledgment is due Prof. John R. Fryer, of the department of oriental languages of the University of California, and to Mr. W. N. Fong, a student in the same institution, for assistance in this part of the work and for other courtesies; also to Mr. Charles Ford, director of the botanic garden at Hong Kong, for identification of the roots of *Pachyrhizus angulatus* and for references to works on the botany of China; and to Prof. W. A. Setchell, of the department of botany of the University of California, for the identification of species of algæ.

On the chemical side of the work the chief difficulty encountered was in the choice of the method of analysis to be employed. The uncertainties involved in many of our present methods of food analysis are too well known to need any extended mention here. In order to make the results comparable with other investigations of a similar nature, the methods outlined by the Association of Official Agricultural Chemists[1] have, for the most part, been adhered to and only such minor modifications have been introduced as the nature of the work seemed to demand.

The substances as purchased in the markets were weighed as soon as possible, and, in the case of fleshy vegetables, the water content reduced by drying in an air bath whose temperature did not exceed 70° C. The residue was allowed to absorb what moisture it would, was then weighed again, and the percentage of loss calculated. This partially dried material was then ground either in a coffee mill or by means of an agate mortar until it all passed through a sieve with 50 meshes to the linear inch and was immediately placed in a tightly stoppered bottle and used for the various determinations. The residual water was carefully determined both at the beginning and at the end of the analysis by drying in a water bath until the sample ceased to lose weight. In many instances the time occupied in making the entire analysis extended over a period of eighteen months, and some samples showed differences of as much as 2 per cent in the two determinations. In such cases the average of the two determinations was obtained and this average factor was used in reducing the results of the analysis to the figures corresponding to a water-free basis. A few exceptions to this method of procedure are noted in the account of the results of the individual analyses.

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46.

For the determination of the crude protein the Kjeldahl method as adopted by the Association of Official Agricultural Chemists was employed. Albuminoids were determined by the Stutzer method, and, with the exception of the difficulty encountered in filtering and washing the cupric hydrate precipitate, this proved fairly satisfactory. This difficulty was particularly marked in those samples which contained large amounts of starch. In such instances great care had to be exercised to avoid overheating, as this gave a precipitate of such gelatinous character that filtration became impossible.

Various attempts to determine the amido compounds directly, by digestion with 5 per cent hydrochloric acid and distillation of the resulting solution with barium carbonate or magnesium hydrate, either failed to give the entire amount of the amids or were unsatisfactory in the presence of albuminoids. The method of Sachsse was found equally unsatisfactory. Hence it was necessary to report simply the difference between the figures found for crude protein and those found for albuminoids, as "amids by difference."

Although the provisional methods recommended by the association for determining the various members of the carbohydrate group are not entirely satisfactory, they have been followed in general. The results are believed to be more useful than a determination of the whole group by difference.

The determination of crude fiber has been made according to the official method, except that asbestos was used in both filtrations. The method gave concordant results when applied to the same sample, but, owing to the varying degrees of difficulty experienced in making the filtrations, can not be applied to a series of different materials under exactly similar conditions. In applying this method to the two species of fungi analyzed nearly two days were required for both filtrations, during which time the acid and alkali solutions were in contact with the material and must have caused lower results than would have been obtained had the method been carried out under normal conditions.

A total of 53 samples was collected, 42 of which were analyzed. For the sake of convenience they have been divided into a number of groups in reporting and discussing the work.

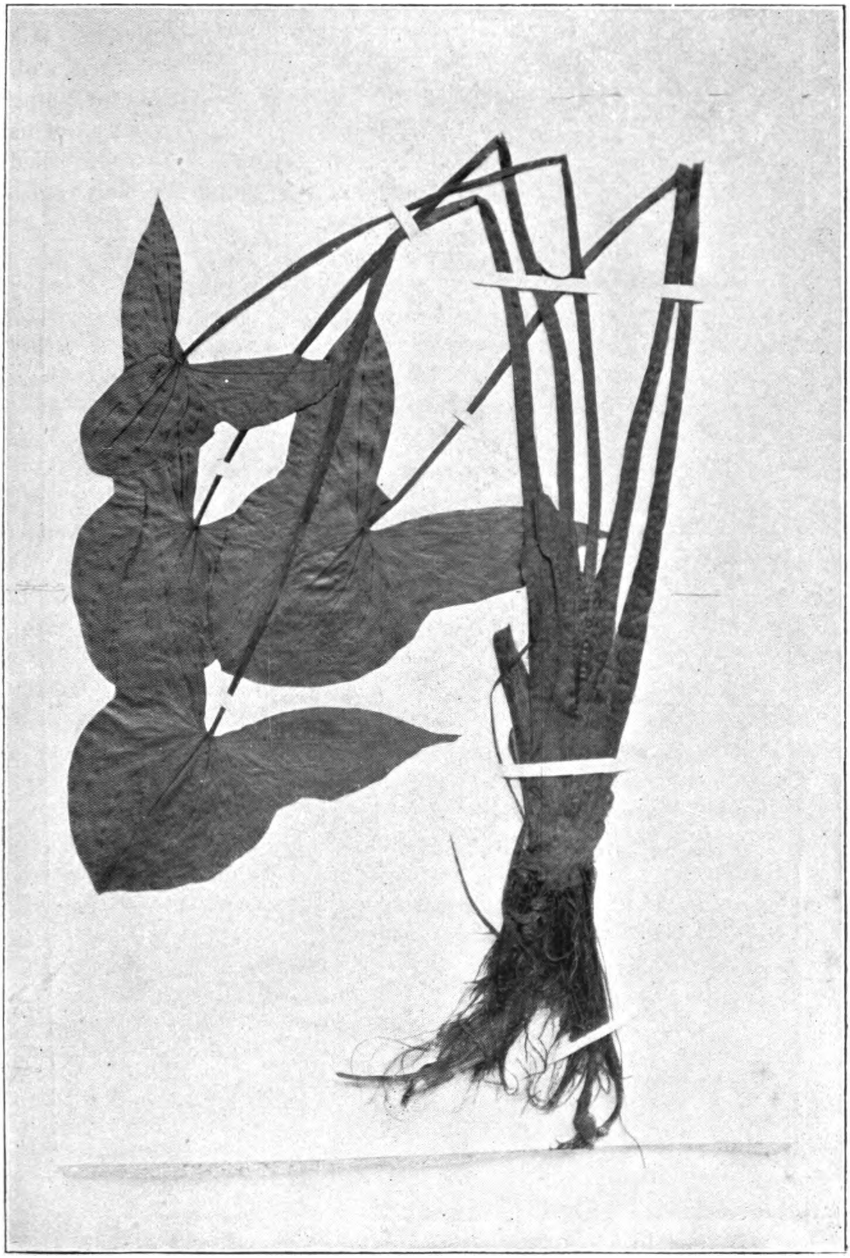
ROOTS AND TUBERS.

SAGITTARIA, OR ARROWHEAD.

The use of the autumn tubers of the various species of Sagittaria, or arrowhead, as articles of food is a common practice among several different races. Lewis and Clarke, in the account of their memorable journey of 1804 across the western United States, make frequent mention of the use of the tubers of *Sagittaria latifolia* (called Wappato) by the Chinook Indians of Oregon. Kalm[1] refers to the use of the roots

---

[1] Pinkerton's Voyages, 13, p. 523.



PLANT FROM AN IMPORTED TUBER OF *Sagittaria sinensis.*

of a species of Sagittaria by the Indians of eastern America. Parry[1] notes the use of the tubers of *S. latifolia* by the Chippewa Indians, and states that in a raw state they contain a bitter, milky juice, but on boiling become sweet and palatable. Finally Coville[2] notes the use of the tubers of *S. arifolia* and *S. latifolia* by the Klamath Indians of Oregon. References to the use of *S. sagittifolia* and *S. sinensis* throughout China, Japan, and portions of India are not uncommon in books of travel relating to these countries, and apparently forms of these species have been in cultivation in the East from very early times. Henry[3] states that the arrowhead (*S. sagittifolia*) is cultivated in all parts of China for its edible tubers, and that there is also a wild form with numerous varieties which produce smaller tubers. The wild form occurs in almost every pool and paddy field. Smith[4] refers to the use of Sagittaria, but the inference from his statement is that it is not very widely cultivated.

The tubers of two species of Sagittaria are found in the Chinese market of San Francisco. Those of *S. latifolia* are not uncommon from October to May, and are known to the Chinese as "t'sz ku" or "chu ko," the former name being the classical one and the latter a provincialism. The characters for them are 茨 菰, but they differ from the characters used in Chinese literature. These tubers are the product of the native American plants which grow abundantly on the "tule lands" bordering the Sacramento and San Joaquin rivers, but, though more largely used, apparently are not esteemed as highly as those of the Chinese species mentioned below. The tubers average about 6 centimeters in length by 2 to 4 in diameter, and weigh about 14 grams each. They are often somewhat flattened laterally and are terminated by an elongated sprout which generally exceeds the length of the tuber itself. In color they are tawny white with often a pronounced bluish tinge, the color being due solely to the very thin, smooth skin. This is crossed by from two to four encircling lines which mark the position of axillary buds. The interior is of about the same consistency as a potato, yellowish in color, and farinaceous in taste.

Well-developed plants were successfully grown from both forms of tubers, which were obtained at different seasons and from different vendors, though none of these plants yielded mature fruit. The method of formation of the tubers is somewhat peculiar. The elongated terminal sprout rapidly develops and soon produces a terminal bud, from which at first roots and then leaves are produced, thus forming an independent plant. This in turn sends out a new series of runners, which behave in the same manner. The original tuber either decays at once or may form more shoots from some of its numerous axillary buds, which in turn give rise to other plants. Toward autumn all the plants which have been thus established develop long runners, each of which bears a single terminal tuber and thus completes the life cycle without the introduction of any sexual process. These features render the plant remarkably prolific.

---

[1] Plants of Wisconsin and Minnesota, Owen's Report, 1852, p. 619.

[2] Contrib. U. S. Nat. Herb., 5 (1897), No. 2, p. 90.

[3] Notes on the Economic Botany of China, p. 27. Shanghai, 1893.

[4] Contributions toward the Materia Medica and Natural History of China, p. 189. Shanghai, 1871.

In the present investigation the author has been unable to study our native Sagittaria with any degree of thoroughness, but it is certain that there are constant differences between the native and imported tubers and the respective plants which may be grown from them. Plate I shows a plant grown from one of the imported tubers. The differences in the two forms of tubers are shown in Pl. II, figs. 3 and 5.

The specific limitations of the members of this genus are not well defined, but there can be but little doubt that the first form of tuber studied is the product of the different varieties of *S. latifolia*, while the second form, in so far as can be determined in the absence of mature akenes, seems to be the product of *S. sinensis*. Both of these species, however, are sometimes regarded as synonymous with *S. sagittifolia*. The leaf characters of the plants produced by the first variety vary considerably, while those produced by the second form are fairly constant. The former commonly produce leaves 1 meter in length with smooth, slender, semiterete petioles, having obtusely pointed apices and divergent lanceolate lobes; also flowers that agree in all essential respects with those of *S. latifolia*. The plant is beautiful, and is well worthy of a place among the ornamental aquatics. Indeed, it is frequently used for this purpose by the Chinese, who grow it in vessels of water in the same manner as they do the Chinese narcissus.

The plants produced by the second form of tuber studied have slightly smaller leaves, with distinctly five-ribbed petioles, a very obtuse apex, and more pronouncedly divergent lobes. The plant has a more stocky habit than the former species, and the tuber-bearing runners are much shorter.

The statement is made by Parish[1] that *S. sinensis* has been introduced by the Chinese into southern California, and by Brandegee[2] that it is common along the Sacramento River. Both these statements, however, are disputed by Smith,[3] and apparently on sufficient grounds.

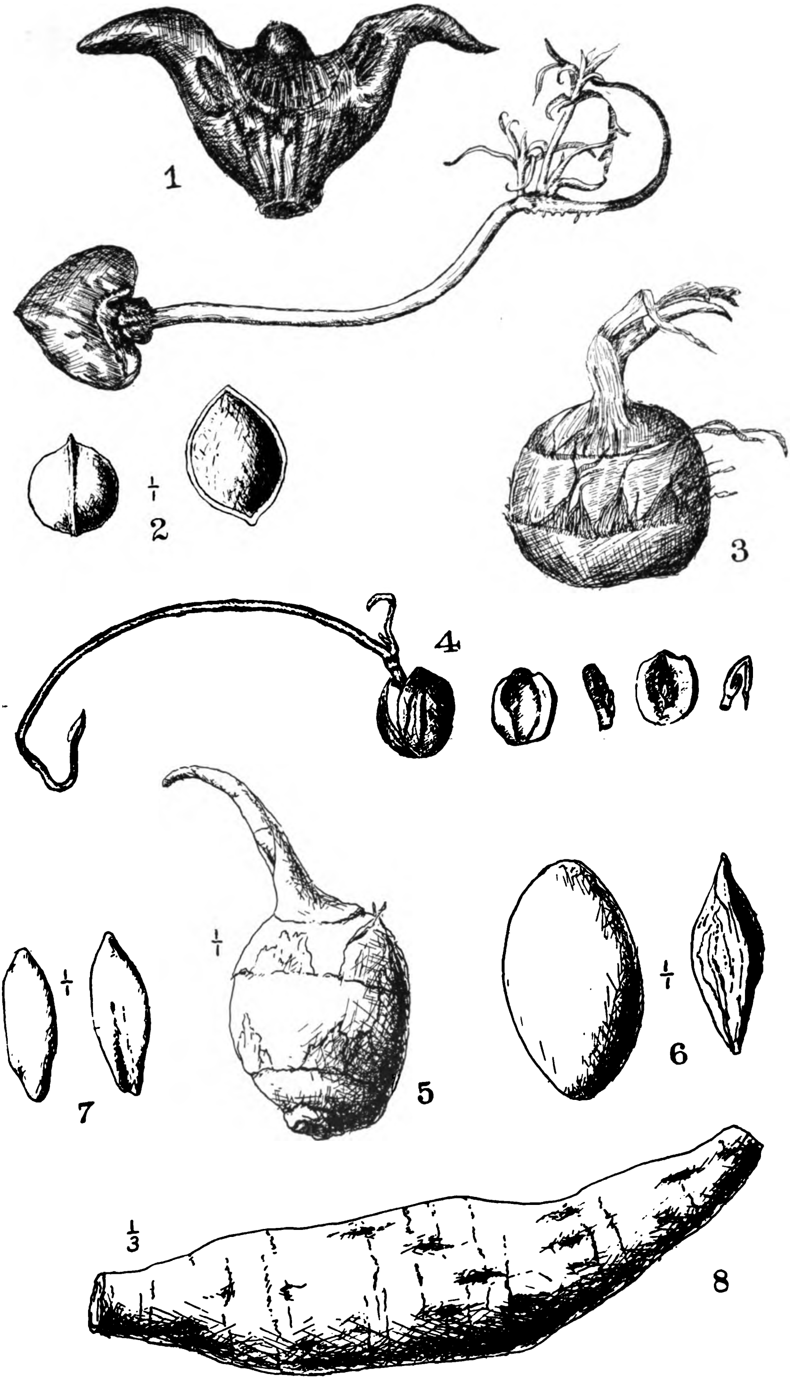
The tubers of *S. sinensis* appear in the markets in December or January, in some seasons in large quantities, and as far as could be learned are always imported from Canton. They are symmetrical and nearly spherical in form, but in size, color, consistency, and other characteristics closely resemble those of the American species and the same Chinese character and name are used for them.

---

[1] Zoe, 1 (1890), p. 122.

[2] Zoe, 4 (1893), p. 217.

[3] Revision of North American Species of Sagittaria and Lophotocarpus, 1894, pp. 9, 12.



Drawings of Roots, Seeds, etc.

1, Seed and young plant of the "horn chestnut" (*Trapa bispinosa*); 2, Seed of *Ginkgo biloba;* 3, Tuber of *Sagittaria sinensis;* 4, Seed and young plant of *Nelumbium speciosum;* 5, Tuber of *Sagittaria latifolia*, sprouted; 6, Fruit and seed of the Chinese olive (*Canarium album*); 7, Kernel of Canarium seed; 8, Root of *Pueraria thunbergiana*.

The starch grains of both species vary from orbicular to ovate in their plane of greatest extent, are occasionally somewhat angled, and seldom exceed 30 μ in diameter (Pl. III, fig. 1). The hilum is somewhat eccentric and the striations are pronounced. With polarized light and a selenite plate they exhibit a slight play of colors.

The composition of the two sorts of tubers is shown in Table 1. The only previous analysis of this vegetable which has been found is reported by Kellner, and represents a Japanese sample of the tubers produced by *S. sagittifolia.* This is included in the table for purposes of comparison.

TABLE 1.—*Composition of arrowhead tubers.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Pentosans.	Crude fiber.	Ash.	Undetermined.
Sagittaria latifolia:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material	66.88	4.44	3.98	0.46	0.76	19.69	[a]2.49	......	0.98	2.04	2.71
Water-free substance	......	13.41	12.02	1.39	2.29	59.46	7.51	......	2.97	6.17	8.19
Sagittaria sinensis:											
Original material	61.51	7.00	4.71	2.29	.24	22.95	[a]2.26	0.32	.72	1.69	3.31
Water-free substance	......	18.18	12.24	5.94	.62	60.89	5.87	.93	1.87	4.38	7.26
Sagittaria sagittifolia: [b]											
Original material	66.86	7.05	5.76	1.29	.55	[c]22.93		......	1.18	1.43	......
Water-free substance	......	21.26	17.38	3.88	1.66	[c]69.21		......	3.56	4.31	......

[a] Sample contained no reducing sugars.

[b] Reported by Kellner, quoted from König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., I, p. 705.

[c] Carbohydrates by difference.

A comparison of the different analyses shows that the figures obtained by Kellner differ little from the results obtained in this laboratory, and in no instance are the differences greater than might have been looked for in tubers grown in different regions. All three analyses show that these tubers contain considerably less water than the majority of our commonly cultivated root crops, and, like most such foods, only small amounts of fat, ash, and crude fiber.

The most striking feature is the high content of crude protein, which, generally speaking, is considerably higher than that of potatoes and similar vegetables. Kellner's analysis gives only total nitrogenous substance, but the other two show a remarkably high percentage of albuminoids, the difference in the crude protein of the two analyses being due almost entirely to nonalbuminoid nitrogenous matter; so that, judging by these analyses, the two forms are about equally valuable as far as albuminoid nitrogen is concerned. The superiority of the arrowhead over the potato in this respect is still more striking when it is remembered that about 50 per cent of the nitrogenous content of the latter vegetable is of a nonalbuminoid character.

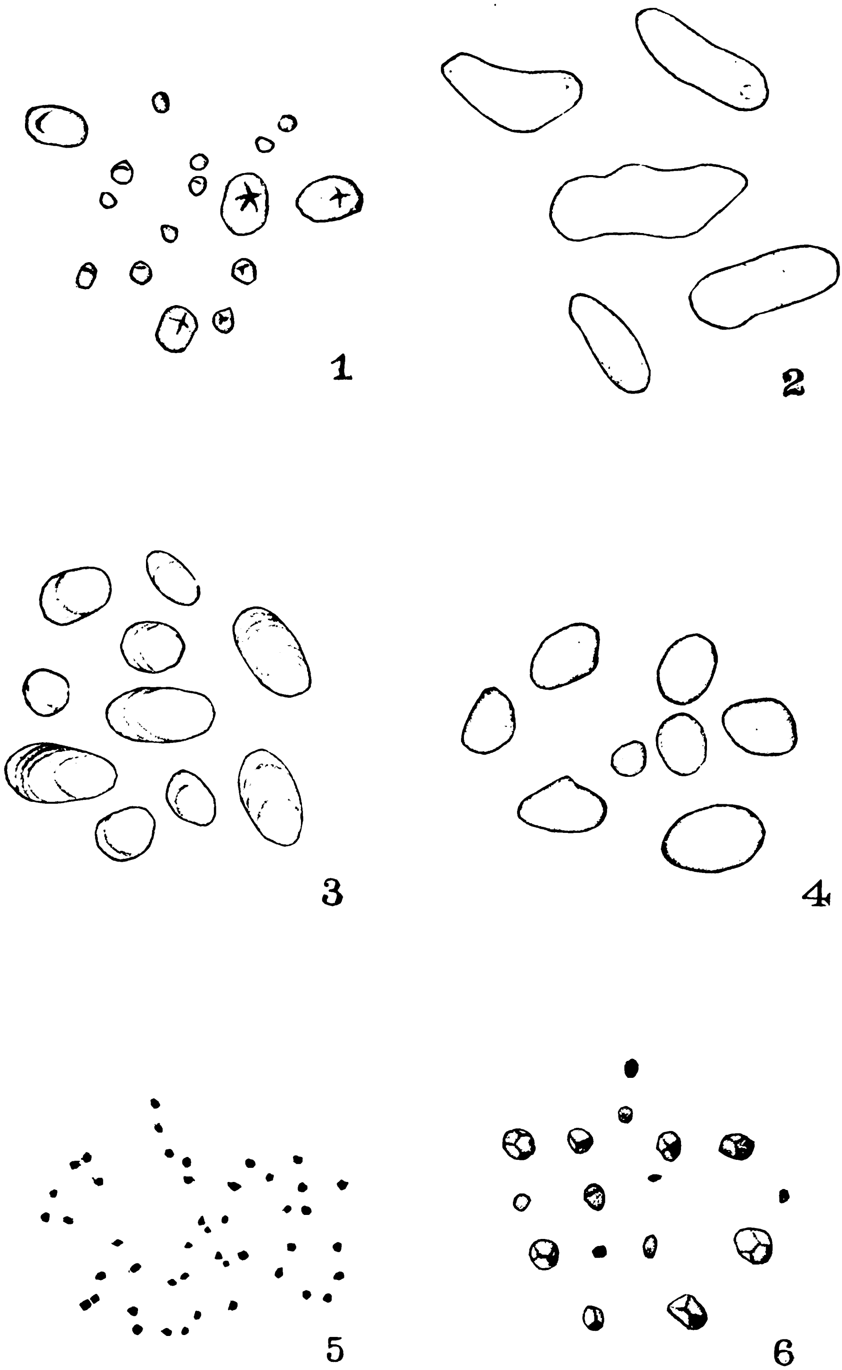
Of the carbohydrate constituents, starch constitutes by far the most important part, though a considerable amount of some member of the cane-sugar group is present. In one analysis a small amount of some reducing sugar was found, but this may have been due to a slight inversion of some body of the cane-sugar group. Furfurol-yielding compounds are also present, though only in small amounts.

Some attempt was made to determine the exact nature of the nitrogenous compounds present. An aqueous extract of the dry residue of the second sample in the table yielded 15.66 per cent of nitrogenous substance; hydrochloric acid added to this extract precipitated 5.96 per cent of the original substance, 97 per cent being of a nitrogenous character. An extract of the freshly crushed tubers gave a precipitate with both potassium ferrocyanid and with phosphomolybdic acid. On heating, this extract gave a heavy coagulum at 74° C., but none above that temperature, though the filtrate from the coagulum still gave a precipitate with both the potassium ferrocyanid and the phosphomolybdic acid. With hydrochloric acid the extract gave a heavy precipitate soluble in a large excess of the reagent. With cupric hydrate it gave a blue solution and a heavy precipitate. When the filtrate from the extract which had been coagulated by heat was evaporated somewhat and allowed to stand, several large colorless crystals resembling in form those of asparagin were obtained. These also gave the well-known reactions of that compound. Hence, it would seem that nitrogenous constituents of the arrowhead tubers consist of (1) a soluble casein-like albuminoid comprising nearly 6 per cent of the dry tubers, (2) a soluble albumen coagulating at 74° C., (3) a small amount of an insoluble albuminoid of an unknown character, and (4) varying amounts of nonalbuminoids of which asparagin is an important constituent.

The total aqueous extract of the dry tubers (the second sample in the table) amounted to 29.18 per cent of the entire weight. Subtracting from this figure those corresponding to the soluble nitrogenous constituents, the soluble ash and the soluble carbohydrates, there remains 3.28 per cent of a soluble substance unaccounted for. The aqueous extract has a peculiar but not unpleasant odor. After coagulating the albuminoids, filtering and evaporating to dryness, there remained a brown sticky mass, very sweet in taste and having in a pronounced degree the peculiar odor of the extract itself. Hence, there is probably at least one unidentified substance which gives to the tubers their peculiar taste. This could not be obtained in a pure condition.

The statement sometimes made that the arrowhead has acrid properties apparently refers only to the leafy portion of the plant, or has arisen from a confusion with some other cultivated water plant.

The foregoing facts seem to warrant the opinion that the arrowhead offers many advantages from a dietetic standpoint. When cooked in the same manner as potatoes, it forms, in the author's opinion, a very acceptable food, though it is not without a pronounced and characteristic flavor. It is stated that some of the poorer non-Mongolian residents of San Francisco have acquired a liking for it and use it freely. The utilization of the arrowhead has already been commented on favorably by



DRAWINGS OF STARCH GRAINS MAGNIFIED ABOUT 480 DIAMETERS.

1, *Sagittaria sinensis;* 2, *Nelumbium speciosum* (roots); 3, *Lilium japonicum brownii;* 4, *Trapa bispinosa;* 5, *Euryale ferox;* 6, *Amorphophallus rivieri.*

Pailleaux and Bois.[1] The tubers might also be used in the manufacture of starch. They are employed for this purpose by the Chinese, and it is said a fine quality of that article is easily prepared from them by the usual methods. The comparatively large areas of land both in California and in other parts of the United States which are too wet for the cultivation of other root crops would seem to offer an especial inducement to considering the utilization of this genius of plants.

TARO.

From remote antiquity the taro has furnished an important item of the food supply of the natives of southern India, Australia, portions of Africa, and many of the islands of the Pacific, and is to-day one of the plants most commonly cultivated throughout the Tropics. Botanically speaking, the taro cultivated for food may be any one of a number of species of the genus Colocasia (also known as Caladium), representatives of the family Aroidæ. The species commonly designated as *Colocasia antiquorum*, of which a large number of varieties are known, seems to be the one most widely cultivated, though *C. indica*, *C. odora*, and *C. macrorhiza*, the two former possibly only varieties of *C. antiquorum*, are said to be extensively used. Most of these species are also used as ornamental greenhouse plants in temperate climates.

Two forms of the taro are sold in large quantities in the Chinese market of San Francisco. Both are said to be imported either from Canton or from the Sandwich Islands. The first, which is the smaller form, is designated by the Chinese characters 芋仔, the second by 粉榔芋. The two forms differ only in size, and produce plants which do not show even varietal differences. Evidently they are the roots of *C. antiquorum*. The smaller form consists of small ovoid or ellipsoid roots about 10 centimeters in length, which weigh from 60 to 70 grams. The larger roots are about 24 centimeters in length, and weigh from 500 to 800 grams. The latter form is considered superior to the former by the Chinese and is sold at a slightly higher price.

The interior of the roots has about the consistency of a sweet potato, and a microscopical examination reveals the presence of large amounts of starch, which is present in the form of exceedingly small grains.

The roots are easily started into growth, and the Chinese market furnishes a cheap source of supply of this well-known ornamental plant.

Several analyses of species of Colocasia have been made by different investigators, most of which, however, are somewhat incomplete. In Table 2 are shown analyses of the two forms studied in this laboratory, one of a small and one of a large root. For purposes of comparison, an analysis by Kellner and one by Nagai and Murai are quoted:

---

[1] Soc. d'Acclimat., 4. ser., 5 (1888), p. 1102.

TABLE 2.—*Composition of taro.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Colocasia antiquorum (small root):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material ...	74.20	1.70	1.67	0.04	0.27	17.95	1.15	.00	0.98	1.31	2.44
Water-free substance	......	6.60	6.46	.14	1.04	69.58	4.45	.00	3.78	5.10	9.45
Colocasia antiquorum (large root):											
Original material ...	67.51	1.89	1.62	.27	.16	25.32	1.86	.00	.66	1.10	3.30
Water-free substance	......	5.51	4.72	.79	.48	73.82	5.43	.00	1.92	3.21	9.63
Colocasia antiquorum: *a*											
Original material ...	80.65	2.09	1.39	.70	.17	6.52	......	......	.70	.85	15.54
Water-free substance	......	10.81	7.18	3.63	.91	33.70	......	......	3.63	4.41	80.24
Colocasia antiquorum: *b*											
Original material ...	85.20	1.43	......	......	.08	10.40	0.12		......	.99	1.78
Water-free substance	......	9.73	......	......	.54	70.26	.81		......	6.69	12.02

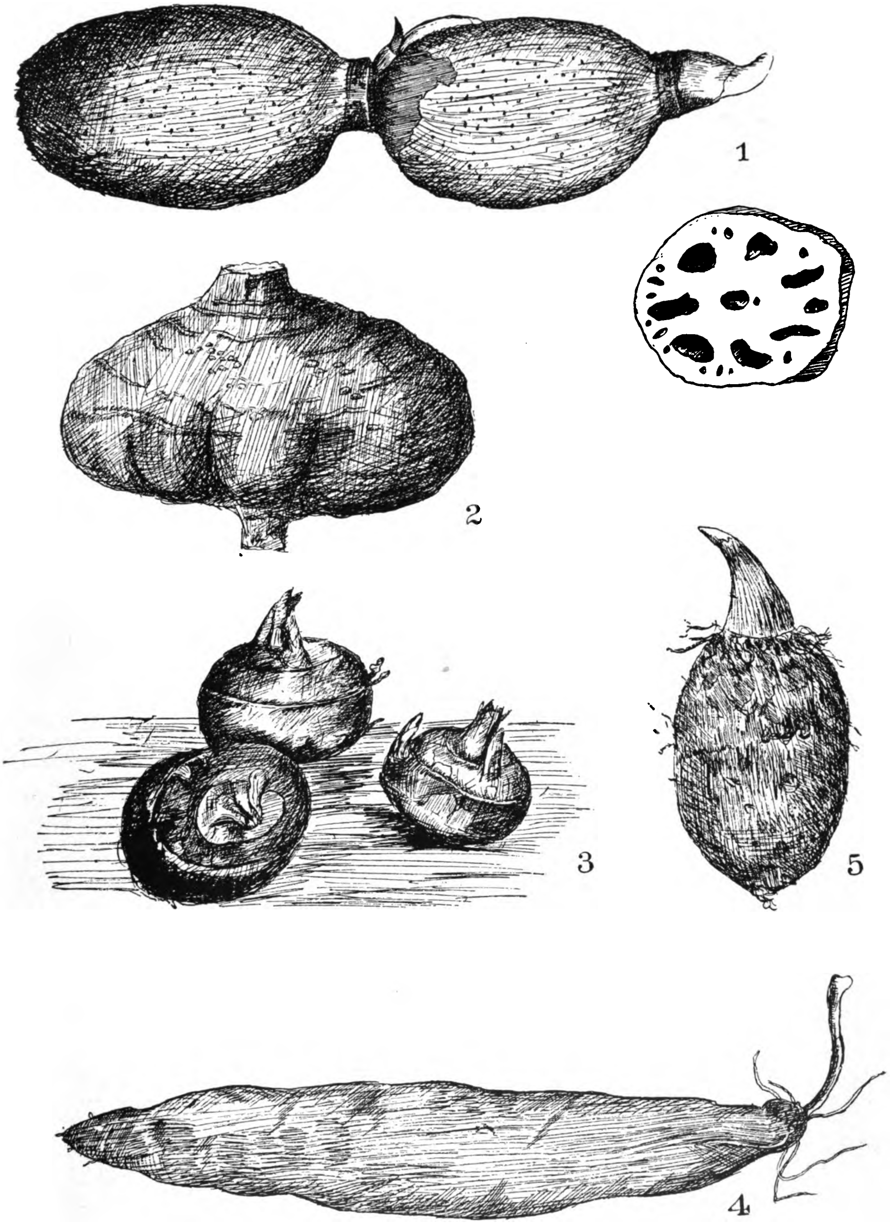
a Reported by Kellner, Landw. Vers. Stat., 30 (1884), p. 42.

b Reported by Nagai and Murai, quoted from König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., I, p. 704.

It is difficult to account for the remarkable difference between the starch content reported by Kellner and that reported in the three other analyses. Both the analyses reported from this laboratory were made in duplicate, with substantially the same results. Kellner states that the roots contain large amounts of reducing sugars. The extremely minute size of the starch grains present renders the separation of soluble from insoluble carbohydrates a very difficult matter. The water extract always showed a slight turbidity, even after several filtrations, and it is possible that a considerable part of the substance reported as cane sugar was really starch in a very finely divided condition.

The protein content shows a considerable variation in the four samples. In all cases it is rather low, but even in the two samples from San Francisco, which give the lowest results for this constituent, the amount present is not far from the average of the results obtained for potatoes and similar vegetables. The analyses also show that a large percentage of the crude protein is of an albuminoid nature, the proportion being somewhat greater than in the case of the potato. Most of this was found to consist of a soluble albumin which coagulates at 74° C. A red coloring matter is present in the taro in considerable amounts.

As a whole the taro is characterized by the high percentage of carbohydrates, of which starch is the most important representative, and by the low percentage of fat and crude fiber. From a dietetic standpoint it apparently offers no especial advantage over our commonly cultivated vegetables, but where it is eaten it seems to be a satisfactory substitute for them. It is favorably known to the Anglo-Saxon residents of the Tropics, who soon acquire a liking for it, and even in San



DRAWINGS OF VARIOUS ROOTS.

1, Portion of the rootstock of *Nelumbium speciosum* and cross section of same; 2, Tuber of *Pachyrhizus angulatus;* 3, The water chestnut (*Eleocharis tuberosa*); 4, A root of Manihot, probably *M. utilissima;* 5, A small form of taro (*Colocasia antiquorum*).

Francisco there is a limited demand among the white races for the roots. A root of *C. antiquorum* is shown in Pl. IV, fig. 5.

The area in the United States suited to the culture of taro is somewhat limited. A patch of it has been growing in the Garden of Economic Plants of the University of California for a number of years, and has produced an abundance of large sound roots. In southern California it makes a rapid growth, but requires an abundant supply of water. The Florida Experiment Station[1] has also experimented with it and reports satisfactory results.

WATER CHESTNUT.

Though several species of Scirpus and the allied genus Eleocharis bear tuber-like roots, they are not commonly considered plants of economic importance by Europeans, and are seldom mentioned outside of the systematic manuals. The water chestnut (*E. tuberosa*) is said to be widely cultivated in China and Japan as a food plant, and is there highly esteemed. In the former countries it is known to the English-speaking residents as the water chestnut, which is but a free translation of "ti leh," one of its Chinese names. Smith[2] says that the tubers are largely cultivated and sold for food all over China. "They grow wild in Hupeh in watery places, and are not often especially planted. They are sweet, juicy, and resemble the chestnut in flavor. * * * A kind of arrowroot [i. e., starch] is made from them." It has also been stated[3] that *Scirpus tuberosus* is cultivated in paddy lands for the sake of its tubers, which are eaten either raw or boiled. Bretschneider[4] states that it is cultivated all over China.

The corms of the water chestnut, for they can scarcely be called tubers, begin to arrive in San Francisco markets in the latter part of May, and are to be found on sale throughout the remainder of the year. They are slightly flattened, about 5 centimeters in diameter, and average about 13 grams in weight. They are surrounded by a rather thick chestnut-brown skin, but within are nearly white and of a somewhat watery consistence. Under favorable conditions those purchased in San Francisco will grow readily and produce an abundance of slender terete culms terminated in some instances by many-flowered spikes. Plate V shows one of these plants. In taste the corms are exceedingly sweet, and also possess a peculiar but not unpleasant flavor. Their only resemblance to the chestnut is in the color of the outer skin. To the Chinese they are known as "ma hai," and are designated by the characters 馬蹄, which differ from any of those used by Bretschneider for the plant. A drawing of three water chestnuts is shown in Pl. IV, fig. 3.

---

[1] Florida Sta. Rpt. 1896, p. 9.

[2] Contributions Toward the Materia Medica and Natural History of China, p. 92. Shanghai, 1871.

[3] Useful Plants of Japan, p. 27. Tokyo, 1895.

[4] Jour. China Branch Roy. Asiatic Soc., 25 (1890–91), p. 47.

As far as observed no analysis of this vegetable has been published. The composition of two samples purchased at different seasons is recorded in Table 3.

TABLE 3.—*Composition of water chestnut.*

	Water.	Proteins.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Eleocharis tuberosa (first sample):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material...	77.29	1.53	1.16	0.37	0.15	7.34	6.35	1.94	0.94	1.19	3.28
Water-free substance............	....	6.73	5.10	1.63	.64	32.30	27.94	8.56	4.12	5.24	14.47
Eleocharis tuberosa (second sample):											
Original material....	77.89	1.31	1.00	.31	.27	8.09	6.02	2.60	1.22	1.18	1.42
Water-free substance............	....	5.91	4.54	1.37	1.23	36.58	27.23	11.78	5.53	5.32	6.42

Much difficulty was experienced in preparing the corms for analysis owing to the high percentage of soluble carbohydrates. This caused them to form a sticky mass, rendering it impossible to reduce the sample to a finely divided condition. Consequently the figures reported for soluble carbohydrates in the analysis of the first sample are probably somewhat low, as is indicated by comparison with the analysis of the second sample in which this difficulty was largely overcome.

On igniting the ash the green color, characteristic of manganese, was always observed. This color was also noted in a large number of the vegetable products grown in China.[1]

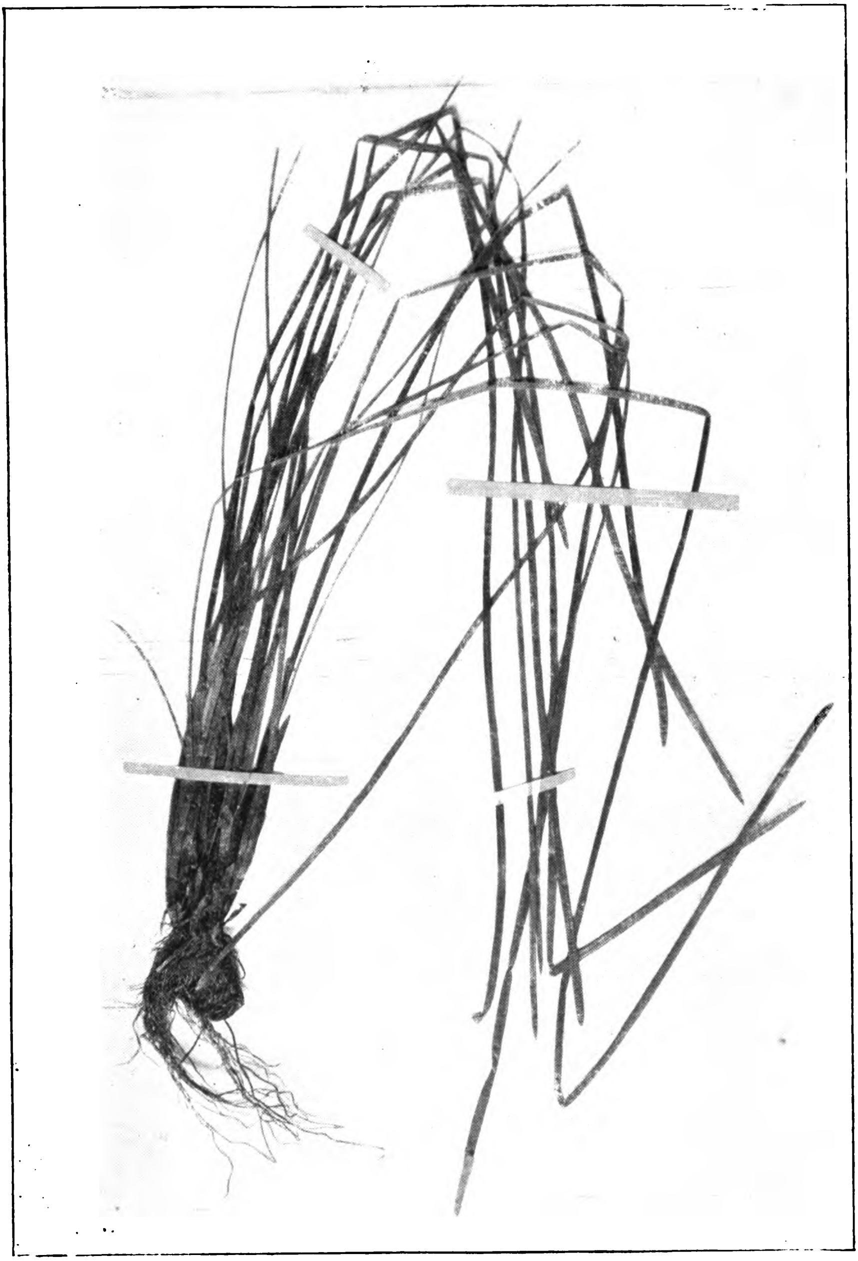
The protein content of the water chestnut is rather low, being even lower than that obtained for the taro, but in respect to this constituent, it will still compare favorably with many of the vegetables in common use. Most of the protein consists of soluble albumin which coagulates at 70° C. The striking feature of both analyses reported is the high percentage of soluble carbohydrates. Presumably these consist very largely of cane sugar, though several attempts to prepare this in crystalline form from water extracts of bulbs were unsuccessful.

As an article of food the roots, in the author's opinion, are very palatable. The high percentage of sugar gives them an agreeable flavor even while raw, in which state they are commonly used by the Chinese.

But little information is accessible regarding the climatic conditions favorable to the development of the plant. The few specimens which were grown under glass seemed somewhat tender, but it is probable

---

[1] This would seem to indicate that too much reliance should not be placed on this test as a means of detecting adulterations in teas.



PLANT FROM A CORM OF *Eleochuris tuberosa*.

that the moister regions of the Southern States or of the interior valleys of California would prove favorable to it. Experiments on this point seem desirable.

SACRED LOTUS.

This plant is better known from the pages of the early classic authors and from tradition than through modern works on economic botany. A plant of such surpassing beauty, whose habit of growth is so unique, could not fail to excite the admiration of all who were permitted to watch its development; and to the people of Egypt and many of the Asiatic countries it assumed the importance of a sacred emblem which was intimately associated with their religion and poetry. In addition to these more æsthetic uses, the plant has from time immemorial been one of economic importance and to-day occupies a not insignificant place in the domestic life of several nations.

One of the most recent accounts of the plant, as viewed in its economic relations, is by Jules Grisard,[1] from which the following facts have been gleaned.

The lotus (Nelumbium) is a native of western India, Persia, Cochin China, and perhaps of Australia, growing in ponds, stagnant water, and rivers. It is cultivated in the basin of the Mediterranean, where there is a summer temperature of about 21° C. In Cochin China it is cultivated in great vases placed at the doors of the houses.

The uses of the lotus are numerous and varied. The stamens are employed in China as an astringent remedy and also for the toilet; the petioles and peduncles furnish a viscous sap employed in India as a remedy for vomiting and diarrhea; the fibro-vascular bundles of the petioles are made into lamp wicks and the carpophore furnishes a popular remedy for blood spitting. The seeds contain a white starch used largely as food (see p. 39); roasted and ground they served the Egyptians for the manufacture of a kind of bread; in China they are used in soup and also as a remedy for indigestion. They are supposed to have invigorative properties when used as food by convalescents. The Chinese also extract from the root a starch which they say is very strengthening. A decoction of the rhizomes is used as a remedy for intestinal inflammation and the rhizomes themselves also become an important article of food in times of famine.

Bretschneider[2] gives an interesting account of the references to the various parts of the plant in the Chinese classics, and Smith[3] gives many notes regarding its varied uses.

The roots or, more strictly, rhizomes of the lotus are brought to San Francisco from Canton in considerable quantities and are on sale in the Chinese quarter throughout the late winter and early spring months. As there found, the yellow nodular root stocks are often 100 centimeters in length, each internode measuring from 10 to 20 centimeters in length by about 7 in diameter. The interior is fleshy, but firm, and of a reddish color. The roots are traversed from end to end by a series of ten or more large radially-arranged tubes, with a number of smaller ones between them. The appearance of one of these roots and of a cross section is shown in Pl. IV, fig. 1. The roots contain an abundance of starch grains, which are oval, elliptical, or narrowly oblong, and exhibit a beautiful play of colors with polarized light and a selenite plate. The stratifications are pronounced.

---

[1] Soc. d'Acclimat., 1896, p. 189.

[2] Jour. China Branch Roy. Asiatic Soc., 25 (1890), p. 216.

[3] Contributions Toward the Materia Medica and Natural History of China, p. 139. Shanghai, 1871.

In San Francisco the roots are known as "lin ngau," though the classical name for the plant is "lien hua." The Chinese characters for them are 蓮藕. As far as could be learned, the roots are used in San Francisco for the preparation of a kind of "arrowroot" (i. e., starch), though several authors state that in China the roots are also boiled and used as a vegetable, or are eaten raw in somewhat the same manner as we use salad plants.

It was found impossible to raise plants from any of these roots purchased in San Francisco. The terminal buds in most instances had been destroyed and the roots seemed to be lacking in vitality. There can be no doubt, however, that the roots in question were those of *Nelumbium speciosum*.

In Table 4 are tabulated two analyses of these roots—one of a sample purchased in San Francisco, and the second, which is included for purposes of comparison, of Japanese roots *N. nucifera* [*speciosum*] reported by Kellner.

TABLE 4.—*Composition of lotus roots.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Nelumbium speciosum:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material	84.26	1.57	0.91	0.66	0.19	7.71	0.33	2.18	0.76	0.76	2.24
Water-free substance	......	9.95	5.79	4.17	1.18	48.99	2.12	13.88	4.83	4.81	14.28
Nelumbo nucifera: [a]											
Original material	85.84	1.09	.73	.36	.20	[b] 11.14			1.02	.71	......
Water-free substance	......	7.75	5.19	2.56	1.41	[b] 78.59			7.20	5.01	......

[a] Reported by Kellner, quoted from König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., 1, p. 705.

[b] Carbohydrates by difference.

The two analyses are remarkably concordant. The water content is considerably higher than that of the vegetables previously mentioned. The protein content is rather low, and of this but little more than half is in the form of albuminoids. The latter fact is not surprising when it is remembered that Kinoshita[1] found about 2 per cent of asparagin in the dry roots of *N. nucifera.* The most valuable ingredient of the root, however, is the starch, which constitutes nearly 50 per cent of the dry substance.

A mucilaginous gum manifests itself whenever the fresh roots are cut, and probably this constituent gave rise to the large amount of undetermined matter found. A red coloring matter, whose nature is unknown, was also present in such amounts as to color deeply the water in which pieces of the root had been boiled.

Though the chemical analysis shows that the rhizomes contain valuable food ingredients, their other qualities are such as are likely to prevent them from forming a satisfactory food according to American standards. The roots are decidedly tough and fibrous and somewhat insipid in taste. Long-continued boiling failed either to soften them or bring them into such a condition that they would be easily digested.

The plant might in all probability be utilized for the production of starch, but whether the product would be equal or inferior to the maranta or tacca starch is not known. The form of the starch grains of *N. speciosum* is shown in Pl. III, fig. 2.

The medicinal properties which have been attributed to the various parts of the plant may be seriously questioned, as the Chinese materia medica presents too many incongruities to permit of placing any great reliance on its teachings.

Experiments in the cultivation of the lotus as an ornamental aquatic have been in progress in various parts of the United States for many years and have been unexpectedly successful. It is found to tolerate the severe winters of the Middle East, and the short but hot summers give it an ample season in which to at least perfect its flowers. It is stated that the plant has become naturalized in a small pond near Bordentown, N. J.[2] California and the Southern States afford many regions that are especially suited to the growth of the plant. In the great interior waterway of the former, comprising the Sacramento and San Joaquin rivers, it could scarcely fail to be successful. Strange to say, this species has proved rather more robust than our own native *N. luteum,* whose seeds and roots, it is said, were utilized as articles of food by the aboriginal races of North America.[3]

LILY BULBS.

Though we are accustomed to consider lilies as plants of ornamental value only, the bulbs and flowers of several species have long been used as articles of food. Nitobe[4] gives a very interesting account of the species in use by the Japanese. Of these, *Lilium glehni* forms the chief vegetable diet of the Ainu, an aboriginal tribe now confined to the islands of Hokaido, but *L. tigrinum* and *L. concolor pulchellum* are the two species most commonly cultivated as articles of food. Penhallow[1] notes the use of *L. cordifolium*, and in a comparatively recent work[2] *L. tigrinum*, *L. auratum*, and *L. elegans* are included among the plants cultivated for their edible roots. Bretschneider[3] also notes the occurrence of several species of lilies with edible roots at Peking, one of which is *L. tigrinum.* Davy[4] notes the use of the bulbs of *L. japonicum brownii*, *L. cordifolium*, *L. tigrinum*, *L. concolor pulchellum*, and *L. glehni*, and the dried flowers of *L. bulbiferum* and *Hemerocallis graminea* as food by the Chinese and Japanese. (See also p. 44.) The author also found the bulbs of *L. parvum* in use by the Washoe Indians of Nevada and those of *L. pardalinum* in use by Indians of northern California.

---

[1] Imp. Univ. Col. Agr. [Tokyo] Bul., Vol. 2 (1895), p. 203.

[2] The Culture of Water Lilies and Aquatics, Peter Henderson & Co., p. 29.

[3] Engelmann, Trans. St. Louis Acad Sci., 2 (1860); Newberry, Food and Fiber Plants of Indians, Pop. Sci. Mo., 32 (1888), p. 31.

[4] Garden and Forest, 9 (1896), p. 12.

From the early part of December to the latter part of August there are found in the Chinese markets of San Francisco the bulbs of a species of Lilium which greatly resemble those of the well-known *L. auratum.* These are sold at the rate of from 10 to 20 cents a pound. They are all imported from Canton. The bulbs have proved to be identical with the ones sold by our nurserymen under the name of *L. brownii*, and this is apparently the only species sold by the Chinese merchants, as a large number of bulbs purchased at different times and from different dealers have invariably yielded plants corresponding to this species. Unfortunately the bulbs are often infested with mites which, either primarily or secondarily, cause the death of the plant before it perfects its flowers. From a collection of over 100 bulbs only 10 perfect flowers were secured.

The name *L. brownii* seems to have been first published by Poiteau,[5] but has since been regarded as synonymous with *L. japonicum*[6] or has been reduced to merely varietal significance. The latter disposition has been adopted here as being the most desirable from a cultural standpoint.

What seems to be the same species may also be obtained in a dry form throughout the year, and both this and the fresh bulbs are known under the name of "pak hop," and designated by the Chinese characters 百合.

In Table 5 the analyses of lily bulbs purchased in San Francisco are reported. One of them was of fresh the other of dried bulbs. Two analyses of Japanese-grown bulbs are also quoted for purposes of comparison.

---

[1] Amer. Nat., 16 (1882), p. 119.

[2] Useful Plants of Japan. Tokyo, 1895.

[3] Jour. China Branch Roy. Asiatic Soc., 15 (1880), p. 179.

[4] Erythea, 6 (1898), p. 26.

[5] Rev. Hort., 2. ser., 2 (1843–44), 496, quoted from Index Kewensis, 3 (1894), p. 81.

[6] Baker, Revision of Tulipeæ, 1875.

TABLE 5.—*Composition of lily bulbs.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Lilium japonicum brownii (dried bulbs):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	10.16	5.57	5.00	0.57	0.37	62.65	2.84	0.00	1.64	2.68	14.09
Water-free substance	....	6.20	5.56	.64	.41	69.73	3.16	.00	1.82	2.98	15.68
Lilium japonicum brownii (fresh bulbs):											
Original material....	66.72	2.33	1.55	.83	.59	17.74	4.16	.00	.75	1.24	6.42
Water free substance	....	7.01	4.50	2.51	1.78	53.40	12.51	.00	2.25	3.74	19.32
Lilium tigrinum: [a]											
Original material....	71.46	4.51	....	....	.24	[c]21.60			1.04	1.15	......
Water-free substance	....	15.79	....	....	.84	[c]75.70			3.64	4.03	......
Lilium sp. ("Yuri"): [b]											
Original material....	69.63	3.40	....	....	.11	[d]19.10	....	....	1.42	1.35	......
Water-free substance	....	11.19	....	....	.05	62.83	....	....	4.66	4.44	......

[a] Reported by Kellner, quoted from König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., I, p. 704.

[b] Reported by Nagai and Murai, quoted from König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., I, p. 705.

[c] Carbohydrates by difference.

[d] In addition the authors report in the fresh substance 0.62 per cent of glucose, 2.44 per cent of pectose, and 1.92 per cent of dextrin.

Wide differences are to be noted between the composition of the two samples of bulbs purchased in San Francisco and the Japanese bulbs. This is not surprising when it is remembered that the bulbs were of different species and were grown in different countries.

The protein content is much smaller in the samples of *L. brownii* than in the others. In all the analyses the amount of protein is somewhat above the average amount found in the potato. The percentage of albuminoids is noticeably greater than in the potato. Starch forms by far the most important constituent of the bulbs and is present in sufficient amount to warrant the belief that they have a high nutritive value (Pl. III, fig. 3). The analysis quoted by Nitobe is interesting as giving somewhat definite information concerning the distribution of the carbohydrates, though he gives no statement as to the methods used in obtaining these results. Without them an accurate knowledge of the compounds present is scarcely possible. In the samples analyzed in this laboratory no cane sugar was found, though the presence of an abundance of mucilaginous or pectose-like substance was easily recognized.

The Chinese regard lily bulbs more as a delicacy than as a standard article of diet, and the customary price is considerably above that of other vegetables in common use by them. A Japanese friend informed the author that they are regarded by the Japanese as an especially desirable food for invalids and convalescents. When used for this purpose the bulbs are only slightly cooked and are eaten after the addition of sugar.

The bulbs sold in San Francisco, as far as the author's observations go, are nearly devoid of the bitter principle which is reported to occur in several species of Lilium. When simply boiled, they form a palatable food, and Americans might doubtless soon become accustomed to their use. The cultural conditions favorable to the production of *L. brownii* or of some of the other edible species are not difficult to find in our own country, though it is very doubtful whether they can be grown as cheaply as our other commonly cultivated vegetables. One valuable feature of the bulbs is the ease with which they may be dried, the resulting product being quite as acceptable as the fresh bulbs. The value of lilies as ornamental plants under present conditions would doubtless prevent their extended use as food in this country.

CHINESE SWEET POTATOES.

Two peculiar varieties of the sweet potato are on sale in the Chinese quarter of San Francisco and are noteworthy from the fact that they are the only edible roots found there which are familiar in American homes. One of these is a yellow variety with somewhat angular-pointed roots. It was at first supposed to be a true yam, or Dioscorea, but by growing a plant from one of the tubers it was shown that they were the product of *Ipomœa batatas* (番薯). This plant produced the lobed leaves characteristic of the yam-like varieties of the sweet potato, but it was impossible to connect it with any of the American varieties of which descriptions were accessible.[1]

A second red variety of *I. batatas* with rounded ends, which is also different from our commonly cultivated forms, is largely used by the Chinese. A plant grown from one of these roots produced the cordate leaves characteristic of a large number of varieties of this species. In Table 6 is shown the composition of the two sorts of Chinese sweet potatoes. The composition of the average of a number of American varieties is quoted for purposes of comparison.

TABLE 6.—*Composition of sweet potatoes.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Ipomœa batatas (roots with pointed ends):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Original material	73.44	0.78	0.77	0.01	0.25	14.65	1.71	4.07	1.02	0.85	3.22
Water-free substance	....	2.95	2.90	.05	.95	55.16	6.43	15.34	3.85	3.20	12.12
Ipomœa batatas (roots with rounded ends):											
Original material	77.47	.73	.70	.03	.22	9.67	4.02	3.19	.93	1.00	2.76
Water free substance	....	3.26	3.11	.15	.98	42.93	17.88	14.16	4.13	4.42	12.23
American sweet potatoes (average of 95 analyses): *a*											
Original material	69.0	1.80	....	....	.70	*b* 26.1			1.3	1.10	......
Water-free substance	....	5.81	....	....	2.26	*b* 84.19			4.19	3.55	......

a U. S. Dept. Agr., Office of Experiment Stations Bul. 28 (rev. ed.), p. 68.
b Carbohydrates by difference.

---

[1] For description of these, Texas Sta. Bul. 28, Georgia Sta. Bul, 30, and Louisiana Sta. Bul. 13 were consulted.

As shown by their composition neither of the Chinese sweet potatoes possesses any advantage over the ordinary American varieties. Both of these forms of sweet potato are said to be grown in California, but they are probably of Chinese origin. Apparently they possess no features which would render them worthy of introduction.

YAM BEAN.

The name "fan ko" is used by the Chinese of San Francisco to designate two different tuberous roots. One of these is globular or napiform in shape and varies from 1 to 2 decimeters in diameter. It is covered with a thick, yellow, stringy bark, which readily peels off and leaves a white fleshy interior of firm consistency and sweet taste. It agrees well with the root described by Henry[1] under the Chinese name given above, and the characters there used for this name (番葛) are the same as those used in San Francisco. Henry surmises that this is the root of *Pachyrhizus angulatus* (Pl. IV, fig. 2), a leguminous vine which is a native of Central America and is now widely diffused throughout the Tropics, although he was unable to secure definite proof of this statement. As it was found impossible to cause these roots to grow, a letter of inquiry was addressed by the author to Mr. Charles R. Ford, director of the Botanic Gardens at Hongkong, regarding them. In reply Mr. Ford stated that he had proved by actual experiment that the roots described by Henry were the product of *P. angulatus*.

The current descriptions of this plant give but little information regarding the character of the root. It is stated by one authority[2] that there is a cultivated form of the yam bean properly referred to *Dolichos tuberosus*, but later transferred to the genus Pachyrhizus by Sprengel, which differs from *P. angulatus* in the more rounded, nondentate leaves, the white and not violet flowers, and the larger pods. The opinion is also advanced that this form is specifically distinct, and that the name *P. tuberosus* should be adopted provisionally. Forbes and Hemsley[3] recognize only *P. angulatus* from China, and this is said to be in cultivation. Fawcett[4] states that the root of *P. tuberosus* is formed of a number of simple cord-like fibers, several feet in length, stretching under the surface of the ground, bearing in their course a succession of tubers. This description is in entire accord with the roots found in San Francisco. These have been called in this bulletin *P. angulatus* without, however, expressing any opinion whether the form known as *P. tuberosus* is distinct.

The composition of *P. angulatus* purchased in San Francisco and of *P. angulatus* and *P. tuberosus* grown in British Guiana, analyzed by Harrison and Jenman, is shown in the following table:

---

[1] Notes on the Economic Botany of China, p. 58. Shanghai, 1893.

[2] Kew Misc. Bul., 1889, pp. 17, 62, 121.

[3] Index Floræ Sinensis, 1887, p. 194.

[4] Economic Products of Jamaica, 1891, p. 37.

TABLE 7.—*Composition of yam bean roots.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Pachyrhizus angulatus:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	78.09	2.18	1.44	0.73	0.18	8.45	3.71	1.84	1.43	0.80	3.31
Water-free substance	....	9.84	6.59	3.35	.80	38.58	16.95	8.41	6.53	3.65	15.14
Pachyrhizus angulatus: [a]											
Original material....	85.70	....	1.04	....	.51	[b] 2.03	....	1.38	.71	1.37	......
Water-free substance	....	....	7.27	....	3.56	14.19	......	9.65	4.96	9.58	......
Pachyrhizus tuberosus: [a]											
Original material....	82.25	....	1.05	....	.30	[c] 8.46	1.29	.26	.66	1.84	......
Water-free substance	....	....	5.91	....	1.69	47.68	7.27	1.46	3.72	10.37	......

[a] Reported by Harrison and Jenman, Rpt. Agr. Work Bot. Gard. British Guiana, 1891-92, pp. 70, 71.

[b] In addition, the authors report in the fresh substance 0.17 per cent resin, 4.30 per cent digestible fiber, and 2.79 per cent gums, pectose, etc.

[c] In addition, the authors report in the fresh substance 0.13 per cent resin, 2.14 per cent digestible fiber, and 1.62 per cent gums, pectose, etc.

The analysis of the roots shows that they contain an abundance of nutritive materials. The protein content is also reasonably high, and viewed in the light of the analysis alone the roots might be pronounced a valuable food.

The roots also contain considerable cane sugar and a large amount of starch. The starch is present in nearly spherical grains which vary much in size. Compound grains or three or more individuals are not uncommon. The hilum is nearly central and is not elongated as in the case of most leguminous starches. No indication of stratification rings could be detected, and polarized light and a selenite plate failed to show a play of colors.

The varieties from British Guiana contain much more fat and ash than the Chinese specimens. The method of reporting the carbohydrates, however, differs from that used by the author, and the results are scarcely comparable. Judged by these analyses the Chinese-grown roots are superior from a dietetic point of view to those from South America.

Harrison and Jenman[1] note the presence of a poisonous resin in the tubers and seeds of *Pachyrhizus tuberosus* and a smaller amount in the seeds of *P. angulatus.* This resin was found to be a very active fish poison.

Long continued boiling of these roots failed to render them even reasonably tender, and left them with a sweet but otherwise insipid taste. The flesh is too tough to admit of being converted into a satisfactory esculent when judged by American tastes, though it has been stated by many authorities that the roots are used in this manner by the Chinese. Macfadyen[2] speaks in the highest terms of the edible qualities of the roots, and Dr. Trimen, of Ceylon,[3] found that both the roots and the green pods formed a valuable vegetable, but the more recent report of Harrison and Jenman[1] (British Guiana), does not praise the edible qualities of the root very highly. Their principal use by the Chinese, however, is for the preparation of a starch which is said to be of a superior quality.

---

[1] Rept. Agr. Work Bot. Gard. British Guiana, 1891-92, p. 70.

[2] Quoted by Fawcett. Loc. cit.

[3] Kew Misc. Bul., 1889, p. 17.

As far as could be learned the Chinese obtain their comparatively large supply of roots entirely from Canton.

The plant requires a warm climate for its development, and probably there are but few localities in the United States in which it could be successfully grown.

A second root, for which the same Chinese name is used, but which is imported to a limited extent only, is often 1 meter in length, with a diameter of only about 12 centimeters. It also has a tough, stringy bark like the former species, and is still more tough and fibrous within than the former roots. There is but little doubt that this is the root of *Pueraria thunbergiana* (Pl. II, fig. 8), a leguminous vine which is a native of China and Japan and greatly resembles the former species. Specimens of this plant have been growing at Berkeley, Cal., for several years, but do not produce roots similar to those sold by the Chinese. This root, designated by the characters 粉葛, is so manifestly unfitted for use as an esculent that the author has not thought it worthy of an analysis. No satisfactory information could be obtained from the Chinese regarding their use of it. The roots are said to be used in China and Japan for the production of starch, and a fiber is also prepared from the stalks of the plant. As an ornamental vine the plants have many valuable features.

CASSAVA, OR MANIOC.

The characters here used 參芙 might be freely translated "the ginseng vegetable," and is not found in the works on Chinese botany or the Chinese-English dictionaries. It is used by the Chinese in San Francisco to designate a peculiar root which is about 5 decimeters in length and 1 in diameter and often weighs as much as 500 grams. The roots taper gradually at both ends and are covered with a gray bark about 8 millimeters in thickness. Within this is found a white sweet flesh which is traversed by a series of fine fibro-vascular bundles. Though it has been found impossible to grow plants from these roots, there is little doubt that they are the product of either *Manihot utilissima* (Pl. IV, fig. 4), the tapioca plant, or *M. aïpi*, the sweet cassava—probably of the former species. The use of the above characters, meaning the ginseng plant, as a means of designating the roots evidently alludes to the habit of the plant itself, as both species of manioc present certain superficial resemblances to the *Panax ginseng* although altogether different botanically. The roots on sale in San Francisco are imported from China, and their principal use is in the preparation of a starch to which medicinal properties are attributed, although probably only from the fancied resemblance of the plant to the true ginseng. The author was also informed that the roots themselves were eaten after long-continued boiling.

---

[1] Loc. cit.

The Division of Chemistry of this Department has published a bulletin[1] on sweet cassava, its culture, properties, and uses. This is based in part on the experience of Florida agriculturists.

The Florida Station has experimented for a number of years with cassava, and has recently published a number of results.[2] The plant has been very successfully grown. The bulletin describes methods of culture, the use of the roots for fattening pigs and steers, and as a food for horses and cows. The roots are also used for the manufacture of starch. In addition, a number of receipts are given for making puddings, fritters, and batter cakes from the freshly grated root. The cassava grown in Florida does not possess poisonous properties.

The composition of manioc, manioc flour, and cassava was also recently reported by Bôname.[3]

An analysis of one of the roots purchased in San Francisco, including the bark, is here reported. Other analyses are quoted for purposes of comparison:

TABLE 8 —*Composition of cassava roots.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Manihot utilissima?:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	80.72	1.58	1.43	0.15	0.17	12.01	0.76	1.59	0.85	0.63	1.69
Water-free substance	....	8.21	7.40	.80	.88	62.28	3.95	8.25	4.43	3.28	8.71
Manihot aïpi: [a]											
Original material....	61.30	.64	....	....	.17	30.98	....	....	.88	.51	5.52
Water-free substance	....	1.66	....	....	.44	80.06	....	....	2.26	1.31	14.27
Manihot utilissima: [b]											
Original material....	67.65	1.17	....	....	.40	23.10	....	....	1.50	.65	[c]5.53
Water-free substance	....	3.62	....	....	1.24	71.39	....	....	4.63	2.01	[c]17.08
Cassava: [d]											
Original material....	66.69	.85	....	....	.18	[e]29.84			1.68	.74	......
Water-free substance	....	2.55	....	....	.54	[e]89.65			5.04	2.22	......

[a] Reported by Wiley, U. S. Dept. Agr., Division of Chemistry Bul. 44, p. 9.
[b] Reported by Payen, Compt. Rend. Acad. Sci. Paris, 44 (1857), p. 401.
[c] Sugars, gums, etc.
[d] Reported by Stockbridge, Florida Sta. Bul. 49, p. 39.
[e] Carbohydrates by difference.

It will be seen that these roots are especially rich in starch, and contain considerable amounts of both cane sugar and reducing sugar. The fat content is low and the protein content somewhat greater than that of the average potato. Nearly 90 per cent of the protein is true albuminoid. It is well known that hydrocyanic acid occurs in most species of manioc, especially of *M. utilissima*, but the temperature at which the above sample was dried previous to analysis should have driven off the greater part of this; and even if present, it is scarcely probable that it would have materially increased the figures for either crude protein or albuminoids on account of the method used for these determinations.

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 44.

[2] Florida Sta. Bul. 49.

[3] Rap. An. Sta. Agron. [Mauritius], 1897, p. 57.

The roots sold in San Francisco evidently differ greatly in composition from those analyzed by Wiley,[1] the ash being much greater, the fat much less, the protein nearly four times as great, and the starch and sugars somewhat less. The analysis of roots of *M. utilissima* quoted from Payen[2] more nearly approaches that of the San Francisco sample.

The starch grains found in the root purchased in San Francisco differ from those commonly figured in illustrating the starch of the sago, and also differ from the grains of *M. aïpi* as given by Wiley.[1] They are commonly oval or oblong and measure on the average 25 by 17.5μ. The hilum is eccentric and the rings prominent.

Judged by the results of the analysis alone, if one has in view the utilization of the plant as a vegetable, the Chinese-grown roots appear to possess decided advantages. If they are the product of *M. utilissima,* however, the presence of hydrocyanic acid in amounts sufficient to render their continued use objectionable is to be feared. If the production of starch or glucose is the object desired, the roots of *M. aïpi* would be the more desirable of the two species, judged by the analyses reported above.

GREEN VEGETABLES AND CUCURBITS.

GREEN VEGETABLES.

The peculiar forms of cabbage and mustard used by the Chinese residents of our Eastern cities have already been fully described by Bailey.[3] Most of the forms there discussed are found on sale in San Francisco, and but little need be added to what he has written regarding their botanical characters.

Brassica pe-tsai, the variety of cabbage known as "pe-tsai," designated by the Chinese characters 白菜, appears to be more largely used and more highly esteemed than any other. This consists of a loosely compacted cluster of tender white leaves with greatly thickened midribs, the whole resembling a head of lettuce rather than a true cabbage. The central axis of the plant, however, extends to about one-half the length of the head. This is the "shantung cabbage," which, though long ago brought to the attention of European seedsmen and gardeners, seems never to have been distributed widely enough to admit of an accurate determination of its merits. The reports of Bailey and others[4] indicate that it has many valuable qualities and might be advantageously brought into more general use.

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 44.

[2] Compt. Rend. Acad. Sci. Paris, 44 (1857), p. 401.

[3] New York Cornell Sta. Bul. 67, pp. 178–191.

[4] Kew Misc. Bul., 1888, p. 137; 1893, p. 344.

Forbes and Hemsley[1] refer the plant specifically to *B. campestris;* Smith,[2] Bretschneider,[3] and apparently most writers on Chinese botany refer it to *B. chinensis;* Loureiro,[4] however, regards it as a form of his *Sinapis pekinensis*, to which he ultimately gave the varietal name of "pe-tsai," and Bailey has raised this name to a specific one.

There are many varieties of "pe-tsai." The one sold in San Francisco differs from that figured by Bailey in the more densely compacted heads and in the greater spread of the leaf blades from the very base of the midrib. One head weighed 750 grams. When tested, this plant seemed to the author an entirely satisfactory vegetable.

The composition of "pe-tsai" is shown in Table 9, p. 32. The analysis there reported shows that this vegetable does not differ greatly as regards food values from our commonly cultivated cabbages. The water content is somewhat greater than the average of the figures for American-grown samples. The protein content is also somewhat lower, but nearly two-thirds of it is of an albuminoid character. The presence of about 30 per cent. of reducing sugar, and also of considerable amounts of starch and small amounts of the cane members of the sugar group, is interesting, but corresponding determinations for other forms of cabbages were not found.

B. chinensis, another largely used cruciferous plant, is sold under the name of "pak-tsai," though the same Chinese character is used to designate it as is used for the former vegetable. The samples found in the San Francisco market are made up into bundles, and consist of either the young and tender leaves or the blanched petioles of the leaves or the stalks derived from the central axis of the plant itself. The latter sometimes show the yellow mustard-like flowers. Bailey designates this plant, though with some hesitation, by the above name, but Forbes and Hemsley include it under *B. campestris*.

The composition of "pak-tsai" is shown in Table 9, p. 32. In composition this vegetable shows nearly the same features as the one previously described except in the case of reducing sugars, which form only about 10 per cent of the dry material. The crude protein is also somewhat lower, but the figures for albuminoids are practically the same. On the whole, as regards composition the vegetable is only slightly inferior to that previously described, and seems worthy of a general trial.

B. juncea.—Still a third cruciferous vegetable is found on sale throughout almost the entire year in San Francisco. It consists of green stalks often 50 centimeters in length, which are usually derived from the petioles only of *B. juncea*, though early in the season the entire leaf is used. This vegetable is known as "kiai tsai," designated by the Chinese characters 芥菜, and is probably a form of *B. juncea*. Bretschneider[1] reports that several varieties of *Sinapis juncea*, or *B. juncea*, are included under the name "kiai tsai" at Peking, and gives the same character as is used in San Francisco for this vegetable. No analysis of "kiai tsai" was made in this laboratory, and none seems to have been reported by other investigators. This species often is sold in a dried form, and is also preserved in brine and used in the same way as sauerkraut.

---

[1] Index Floræ Sinensis, 1886, p. 46.

[2] Contributions Toward the Materia Medica and Natural History of China, p. 42. Shanghai, 1871.

[3] Jour. China Branch Roy. Asiatic Soc., 15 (1880), pp. 34, 124.

[4] Flora Cochinesis, 1790, p. 400.

Amarantus sp.—The young seedling plants of Amarantus are in common use as a pot herb among the Chinese of the Pacific coast. Both our native species and a form which is said to be regularly cultivated are in use. The plants found in market are too immature to admit of specific identification. This vegetable goes under the name of "in tsai," designated by the characters 莧菜, which Bretschneider[2] says is generally applied to several species of Amarantus. Bailey[3] describes a form of *A. gangeticus* used by the Chinese as a pot herb. Smith[4] speaks of the use of *A. oleraceus* and Forbes and Hemsley[5] state that *A. blitum*, *A. caudatus*, *A. gangeticus*, and *A. paniculata* are commonly cultivated as vegetables in China. Several varieties of indigenous Amarantus and the closely related Chenopodiums are eaten to a limited extent in the United States. Their value has been pointed out by Coville.[6]

The composition of Amarantus purchased in San Francisco is shown in Table 9, p. 32. The analysis here recorded presents no unusual features save in the high content of crude protein, in which feature it surpasses the cruciferous vegetables mentioned above.

Solanum melongena.—A peculiar variety of the eggplant, known in San Francisco as "pak ke," designated by the characters 白茄, is one of the noticeable features of the Chinese vegetable stands during the summer months. This has a perfectly smooth white skin and is from 9 to 24 centimeters long and about 10 in diameter. Osbeck, Loureiro, and most of the early writers on Chinese botany speak of the cultivation of the eggplant. The composition of this eggplant is shown in Table 9, p. 32. Apparently but few analyses of this vegetable have been made, but the results obtained from the analysis of the Chinese variety in this laboratory agree quite closely with that of an American-grown specimen.[7] The percentage of sugars and starch is apparently quite large, though the real nature of the carbohydrates is uncertain since they were determined by difference. Starch, however, as shown by qualitative tests in this laboratory, is certainly present in considerable amounts.

---

[1] Jour. China Branch Roy. Asiatic Soc., 15 (1880), p. 92.

[2] Ibid., p. 168.

[3] New York Cornell Sta. Bul. 67, p. 199.

[4] Contributions Toward the Materia Medica and Natural History of China, p. 12. Shanghai, 1871.

[5] Index Floræ Sinensis, 1891, p. 319.

[6] U. S. Dept. Agr., Yearbook 1895, p. 210.

[7] U. S. Dept. Agr., Office of Experiment Stations Bul. 28, p. 38.

CUCURBITS.

The fruits of several species of Cucurbitaceæ are extensively used by the Chinese. Bailey[1] has already given an account of the cultural features and uses of four species, all of which were found on sale in San Francisco and are there used in large quantities. Further information concerning these vegetables is given by Lander[2] and by Georgeson.[3]

Momordica charantia, the "fu kwa" or "khu qua" of Bretschneider, or the "la qua" of Bailey, is designated by the Chinese characters 苦瓜. This vegetable is noted in nearly all works descriptive of the botany of China, where it is largely cultivated and to which country it is probably indigenous. It is also sometimes called "lai kua," or the leprosy gourd. Its immature fruit is largely used throughout the Tropics as a condiment in the preparation of curries, etc. By the Chinese it is used especially in the preparation of salads, etc. The closely related *M. balsamina* is already somewhat widely known in America as an ornamental vine, and the seeds of both species are to be obtained from American seedsmen. The shuttle-shaped green fruits of *M. charantia* are about 2 decimeters in length, covered with rows of wart-like tubercles, and are borne on wiry stems of about the same length. Like all the other green vegetables described above, they are grown in large quantities in the Chinese gardens along the Sacramento River.

The *M. charantia* can scarcely be regarded as a food plant in the narrower sense of that term, as the principal value of its fruits depends upon the flavor they impart to other preparations, rather than on the amount of nutriment they contain. Nevertheless, large amounts of the fruits are eaten, and they must be considered in studying the dietary of the Chinese. The analysis here reported (Table 9, p. 32) shows that the fruit is not lacking in nutritive constituents, though the exact nature of the compounds represented could not be determined without a more extended investigation. The crude fat in this case apparently consisted almost wholly of chlorophyll. Of the 18 per cent of nitrogenous constituents, about two-thirds was of an albuminoid nature. Reducing sugars, or at least soluble carbohydrates having reducing power, were found to be present in considerable quantities, and true starch was also present in relatively large amounts.

Luffa acutangula, is known as "sz kwa," and both this and the following species are designated by the Chinese characters 絲瓜. This is a native of tropical Asia, though naturalized in certain regions of America. The name above given is synonymous with *L. fœtida* and with *Cucumis acutangulus.* The plant produces a green, pronouncedly ten-ribbed fruit, about 3 decimeters in length, which is obtusely terminated at the farther end, but tapers gradually to the point of union with the peduncle. In uses and culinary qualities it much resembles the common cucumber. In San Francisco, it is said, the Chinese use it for thickening soups. Bailey[1] states that it is eaten raw, and also cooked in the same manner as we use squashes. As shown by analysis (Table 9, p. 32), it does not differ greatly from the species previously described, the chief difference being in the lower percentage of nitrogenous substances and in the greater content of carbohydrates, especially of reducing sugars.

---

[1] New York Cornell Sta. Bul. 67, pp. 191–196.

[2] Garden and Forest, 1 (1888), p. 483.

[3] Amer. Garden., 13 (1892), p. 526.

Luffa cylindrica is called by the Chinese "po kua." This is the "sua kwa" of Bailey.[2] This plant is also widely cultivated throughout the Tropics, but its native country is unknown. It is synonymous with *L. ægyptica*, *L. petiola*, and *Momordica cylindrica.* It is reported from China by most of the naturalists who visited that country in early days, as well as by the more recent botanists. Its slender, cylindrical, crooked, yellowish-green fruits, which are often 6 decimeters long, are used in the immature condition in the same manner as we use squashes. The interior of the mature fruit is filled with a fibrous mass, which when dried forms a useful household article. Hence the plant is often known as the "dish-cloth" or "towel gourd," and is more often grown for its fibrous interior than as a food. In San Francisco, however, it is largely used for the latter purpose, being prepared in much the same manner as squashes are treated in American households. As shown by analysis (Table 9, p. 32), it is on the whole about equivalent in food value to the previously-described species, the protein content being somewhat less, while the percentage of reducing sugars and starch is somewhat greater. As shown by comparison, it is rather inferior to the common varieties of squash, and it can scarcely be regarded as more than a passable substitute for them.

Benincasa cerifera.—This plant is known as "zit kwa," and is designated by the characters 節瓜. It is the same as the "tung kua" of Bretschneider,[3] designated by the characters 冬瓜. Under the name of "Chinese preserving melon," it is already somewhat known in the United States. It is a tropical vine, long cultivated in China, Japan, India, and Africa, where it is often met with growing spontaneously, though its native country is unknown. The young green hairy fruits when about 20 centimeters in length, are used in the same manner as we use the squash. The mature fruits often attain a weight of 12 kilograms, are perfectly smooth, and covered with a white wax. With the exception of a small amount of pulpy substance which is filled with the white seeds, the interior is made up of a white solid flesh. The mature fruit is used by the Chinese in the preparation of confections and is also said to be used as a vegetable. The analysis reported below presents no especially interesting features save the high percentage of reducing sugars.

---

[1] New York Cornell Sta. Bul. 67, p. 196.

[2] Ibid., p. 195.

[3] Jour. China Branch Roy. Asiatic Soc., 15 (1890–91), p. 153.

The composition of the green vegetables and cucurbits discussed above is shown in the following table:

TABLE 9.—*Composition of green vegetables and cucurbits.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
GREEN VEGETABLES.											
Brassica pe-tsai:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*
Original material....	95.74	1.19	0.48	0.71	0.15	0.31	0.09	1.29	0.52	0.56	0.14
Water-free substance	....	28.07	11.36	16.71	3.57	7.19	2.11	30.25	12.16	13.28	3.38
Brassica chinensis:											
Original material....	96.55	.78	.41	.37	.10	.31	.09	.37	.46	.65	.80
Water-free substance	....	21.96	11.43	10.53	2.82	8.61	2.45	10.45	12.86	18.33	22.52
Amarantus sp.:											
Original material....	91.52	2.61	1.67	.94	.36	.50	....	....	.92	1.56	2.55
Water-free substance	....	30.80	19.68	11.12	4.26	5.82	....	....	10.81	18.31	30.00
Solanum melongena:											
Original material...	89.62	1.38	1.08	.29	.30	1.57	.63	1.31	1.54	.69	2.95
Water-free substance	....	13.25	10.42	2.83	2.91	15.11	6.10	12.66	14.88	6.69	28.39
CUCURBITS.											
Momordica charantia:											
Original material....	93.61	1.18	.79	.39	.20	.67	.06	.60	1.07	.34	2.28
Water-free substance	....	18.48	12.31	6.18	3.19	10.56	.74	9.36	16.72	5.25	35.69
Luffa cylindrica:											
Original material....	94.66	.51	.38	.13	.19	1.04	.12	2.15	.46	.41	.45
Water-free substance	....	9.57	7.07	2.50	3.72	19.52	2.18	40.29	8.58	7.65	8.49
Luffa acutangula:											
Original material....	94.90	.68	.54	.14	.24	.36	.10	1.57	.72	.43	1.00
Water-free substance	....	13.39	10.68	2.71	4.70	7.03	1.95	30.86	14.03	8.43	19.61
Benincasa cerifera:											
Original material....	96.24	.50	....	....	.16	.31	.07	.90	.57	.35	.88
Water free substance	....	13.27	....	....	4.34	8.29	1.74	24.19	15.19	9.48	23.49

SEEDS AND GRAINS.

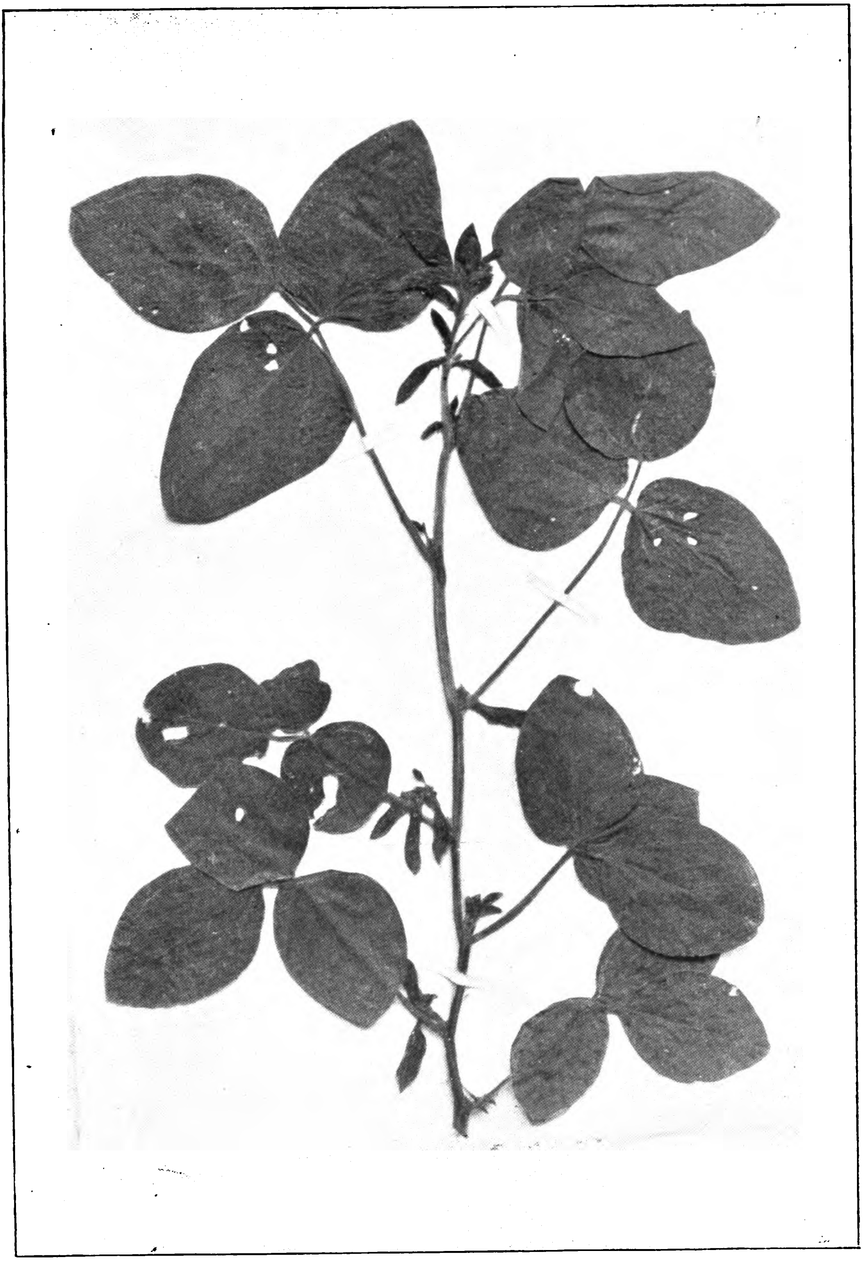
SOY BEANS.

Leguminous seeds and certain preparations made from them have always formed an important part of the largely vegetarian diet of the Chinese and Japanese. Of the legumes the soy bean, *Glycine hispida* (*Soja hispida*), is the most important. The soy bean has long been known in Europe. Kaempfer[1] was perhaps one of the first Europeans to describe it. This plant has been cultivated many years in Europe, and is coming to be quite extensively grown in the United States, largely for use as a forage plant. The soy bean has been treated of in a previous publication[2] of this Department. A large number of varieties of the soy bean are in cultivation in China and Japan, but only two were found in the Chinese markets in San Francisco, a yellow and a black variety. Aside from a difference in color, the two forms

---

[1] Amœnitatum Exoticarum, p. 837. Lemgoviæ, H. W. Meyer, 1712.

[2] U. S. Dept. Agr., Farmers' Bulletin 58.



UPPER PORTION OF A PLANT OF THE BLACK SOY BEAN.

apparently do not differ materially from each other. The yellow variety is known as "wong tau," and is designated by the characters 黃荳, while the black is known as "hak tau," and is designated by the characters 黑荳. The soy bean resembles a pea rather than a bean, although the botanical characteristics of the plant indicate that it is very different from any of our cultivated peas or beans.

Both varieties obtained from the Chinese market in San Francisco grew readily in Berkeley, attaining a height of about 3 feet, and in spite of a very dry season produced an abundant crop of seeds. The appearance of two of these plants at different stages of growth is shown in Pls. VI and VII. The composition of the seeds of the two varieties is shown in Table 10, the average composition of American-grown soy beans being quoted also for purposes of comparison.

TABLE 10.—*Composition of soy beans.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Glycine hispida (black):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P ct.*
Original material....	8.25	36.35	34.63	1.72	17.22	6.80	7.38	0.00	5.25	4.77	13.98
Water-free substance	....	39.62	37.74	1.82	18.77	7.41	8.04	0.00	5.72	5.20	15.25
Glycine hispida (yellow):											
Original material....	8.33	36.00	35.54	.46	17.87	5.87	6.55	0.00	5.43	4.75	15.20
Water-free substance	....	39.27	38.77	.50	19.49	6.40	7.14	0.00	5.92	5.18	16.59
Glycine hispida (average of 8 analyses): *a*											
Original material....	10.80	33.98	....	....	16.85	*b* 28.89			4.79	4.69	......
Water-free substance	....	38.1	....	....	19.00	*b* 32.2			5.4	5.3	......

a U. S. Dept. Agr., Office of Experiment Stations Bul. 11, p. 120.
b Carbohydrates by difference.

The analyses of these two Chinese varieties of soy beans, as well as of others which have been published, show that they contain an unusually large amount of valuable food constituents, especially protein and fat, the former constituting about 39 and the latter about 19 per cent of the total weight. As shown by the analysis made by the author, nearly all the protein is made up of albuminoids. The figures obtained by the author for cane sugar and starch indicate that a considerable amount of carbohydrates was present, although starch could not be detected by the ordinary test. No special attempt was made to separate the cane sugar.

There has been considerable difference of opinion among investigators regarding the presence of starch in soy beans. The weight of evidence, however, seems to indicate that, under certain conditions, starch in considerable amounts may be present. In 1880 Meissl and Böcker[1] investigated soy beans and reported the presence of starch. The amount of starch found was said to be less than 3 per cent. The starch grains are described as being extremely small and as differing in form from the typical bean or pea starch. About the same time Hanausek[1] also reported starch in soy beans. It was found deposited where the surface of the cotyledons met, and according to the author, could not be detected by the usual chemical methods. The starch grains were embedded in fat and gave no color reaction after prolonged treatment with iodin. A more extended study of soy beans was reported by Harz.[2] According to this author, when the beans do not ripen thoroughly, or when allowed to ripen after the vines are cut, they may contain starch, some varieties being more likely to contain it than others. Inoyue[3] also was unable to find starch in the mature seeds.

---

[1] Sitzber. Math. Naturw. Cl. Akad. Wiss. (Vienna), 87 (1883), pt. 1, pp. 372–391.

The carbohydrates other than starch in soy beans have been studied by many investigators. Stingl and Morawski[4] report the presence of small quantities of dextrin in soy beans, and about 2 per cent of a mixture of different sugars which could be readily fermented. Their investigation was principally concerned with the diastatic ferment found in the beans. A number of tests on the quantity of the ferment are reported. La Vellois[5] reported the presence of 9 to 11 per cent of material soluble in alcohol, which did not reduce Fehling's solution. Tollens[6] calls this substance galactan. Schultz and Frankfurt[7] proved the presence of cane sugar in soy beans. Maxwell[8] identified paragalactan, an insoluble carbohydrate. A number of other investigations on the carbohydrates of soy beans have been reported.

In 1880 Meissl and Böcker[9] reported an extended investigation of the proteids of soy beans. According to these investigators the beans contained the following proteids: A so-called "casein" (27.6 per cent), albumen (0.5 per cent), a proteid precipitated by cupric oxid and potassium hydroxid (2.5 per cent), and, in addition, a very small amount of nonalbuminoid nitrogenous substance. Osborne and Campbell[10] have recently reported an extended study of the proteids of soy beans. The principal proteid found is called "glycinin." It is a globulin. According to these authors the beans also contain about 1.5 per cent of an albumin-like proteid, legumelin. A small amount of proteose was also found.

Meissl and Böcker[9] studied the fat of soy beans, which is said to contain no free fatty acid and to consist almost entirely of neutral trigly-

---

[1] Ztschr. Allg. Oester. Apoth. Ver., 22 (1884), p. 474.

[2] Ztschr. Allg. Oester. Apoth. Ver., 23 (1885), p. 40; Landwirtschaftliche Samenkunde, p. 692. Berlin, P. Parey, 1885.

[3] Imp. Univ. Col. Agr. [Tokyo] Bul., Vol. 2, No. 4.

[4] Monatsh. Chem., 7 (1886), pp. 176–190.

[5] Compt. Rend. Acad. Sci. Paris, 93 (1881), p. 281.

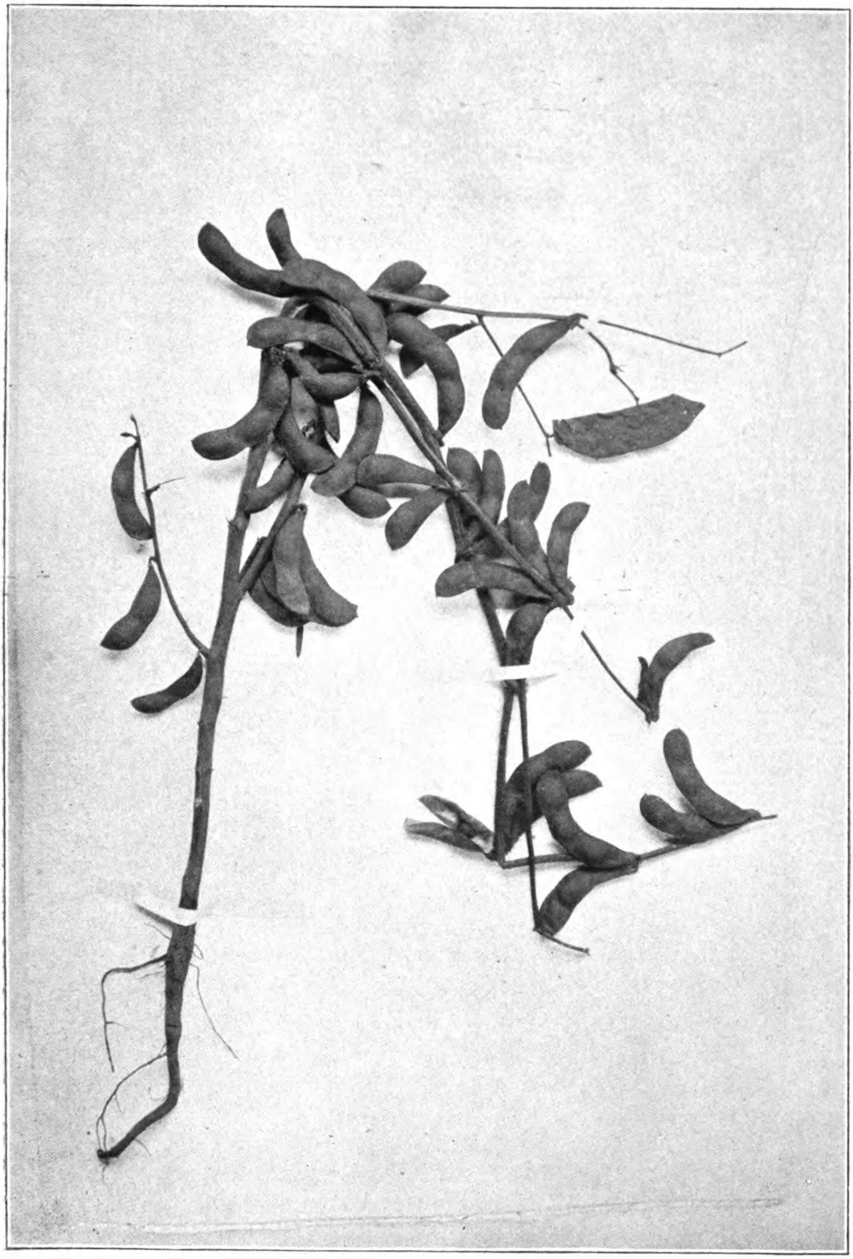
[6] Handbuch der Kohlenhydraten, vol. 1, p. 208. Breslau, E. Trewendt, 1888.

[7] Ber. Deut. Chem. Gesell., 27 (1894), p. 62.

[8] Amer. Chem. Jour., 12 (1890), p. 51–60.

[9] Loc. cit.

[10] Conn. State Sta. Rpt. 1897, pt. 4, pp. 374–382.



MATURE PLANT OF YELLOW SOY BEAN.

cerids. At a low temperature or on standing a long time the palmatin and stearin triglycerids were precipitated in crystalline form. The fat has a characteristic leguminous taste. When kept for two years it became thick, but was only slightly rancid. Its specific gravity was 0.89 at 15° C. One gram of soy-bean fat required 191.8 milligrams potassium hydroxid for saponification. The fat has also been examined by Stingl and Morawski[1] and by Roelofsen[2] with reference to its iodin absorption. The figures obtained for the latter constant were 121.3 and 138.8, respectively, and these and other facts indicate that the oil has poor drying properties.

Pellet[3] studied the ash of soy beans in considerable detail.

Soy beans are eaten to some extent when cooked in the same ways as other beans. The Chinese express an oil from them which is a standard article of commerce and is largely used in cooking. The principal use which they make of the soy beans, however, is in the preparation of a vegetable cheese, a kind of thick sauce, and other products. An account of the manufacture of miso and soy-bean sauce in the early part of the eighteenth century is given by Kaempfer.[4] According to Prinsen-Geerligs,[5] "tao hu," or bean cheese, is prepared from the seeds of the white variety of soy bean. These are allowed to soak for three hours in water, are then reduced to a thick paste, and the mass cooked. The cooked mass is strained through a coarse cloth. The filtrate consists of a milky-white liquid containing protein and fat. As soon as this becomes cool some material is added (for instance, crude salt containing magnesium chlorid), which precipitates the proteid material, the fat being inclosed in the coagulated mass. The coagulated material is pressed and kneaded into small cakes. The cakes may be dipped for a few moments into a saline solution of curcuma. Variations in the process give rise to a number of varieties of bean cheese. This is essentially the method used by the Chinese of San Francisco in the preparation of the bean cheese used by them. It is sold either in the form of the freshly precipitated curd or in the form of small square cakes obtained by compressing the former material. It is usually cooked in peanut oil before being eaten and, in the author's opinion, is a palatable food. A partial analysis of one of these cakes gave water 81.35 per cent, fat 5.19 per cent, and ash 0.80 per cent.

The filtrate from the cooked soy beans resembles milk, and, on heating, a skin, not unlike that formed on milk, rises to the surface of it.

A thick sauce called "tao yu," resembling the Japanese "shoju," is also prepared from the soy beans, as well as a thick condiment called "tao tjiung," similar to the Japanese "miso." According to Prinsen-Geerligs, these preparations have the following composition:

---

[1] Chem. Ztg., 10 (1886), p. 140.

[2] Amer. Chem. Jour., 16 (1894), p. 49.

[3] Compt. Rend. Acad. Sci. Paris, 90 (1890), pp. 1177–1180.

[4] Loc. cit.

[5] Chem. Ztg., 20 (1896), pp. 67–69.

Table 11.—*Composition of Chinese soy-bean preparations.*

	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Undetermined.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Tao hu (bean cheese)	76.15	13.15	7.09	1.40	2.21	....
Milk from boiled soy beans	93.10	3.13	1.89	....	0.51	....
Tao yu (soy sauce)	57.12	7.49	....	16.03	*a* 18.76	....
Tao tjiung	62.86	12.67	1.21	*b* 13.78	6.71	2.77

a Including 17.11 sodium chlorid.
b Including 3.78 crude fiber.

The Japanese preparation made from soy beans, similar to those mentioned above, have been described by a number of investigators. A brief account of them has been given in a previous publication of this Department.[1] As shown by their composition, these soy-bean preparations contain a high percentage of nutrients. They are eaten in large quantities and form important articles of diet. A number of digestion experiments have been reported in which the Japanese preparations formed a considerable part of the diet, and on the basis of the results obtained the preparations are considered to be very well assimilated.

PHASEOLUS.

The seeds of two varieties of *Phaseolus mungo* are largely used by the Chinese in San Francisco. One of these, known as "luk tau," designated by the characters 綠荳, is a small green bean. The individual seeds weigh only about 0.044 gram. They are slightly flattened at the ends and have a rather long hilum. Plants were grown at Berkeley, Cal., from these seeds and yielded a good return, though the plant was not as prolific as the soy bean. The appearance of one of them is shown in Pl. VIII. The analyses in the table below show that these beans differ in composition but slightly from the commonly cultivated varieties of *P. vulgaris.*

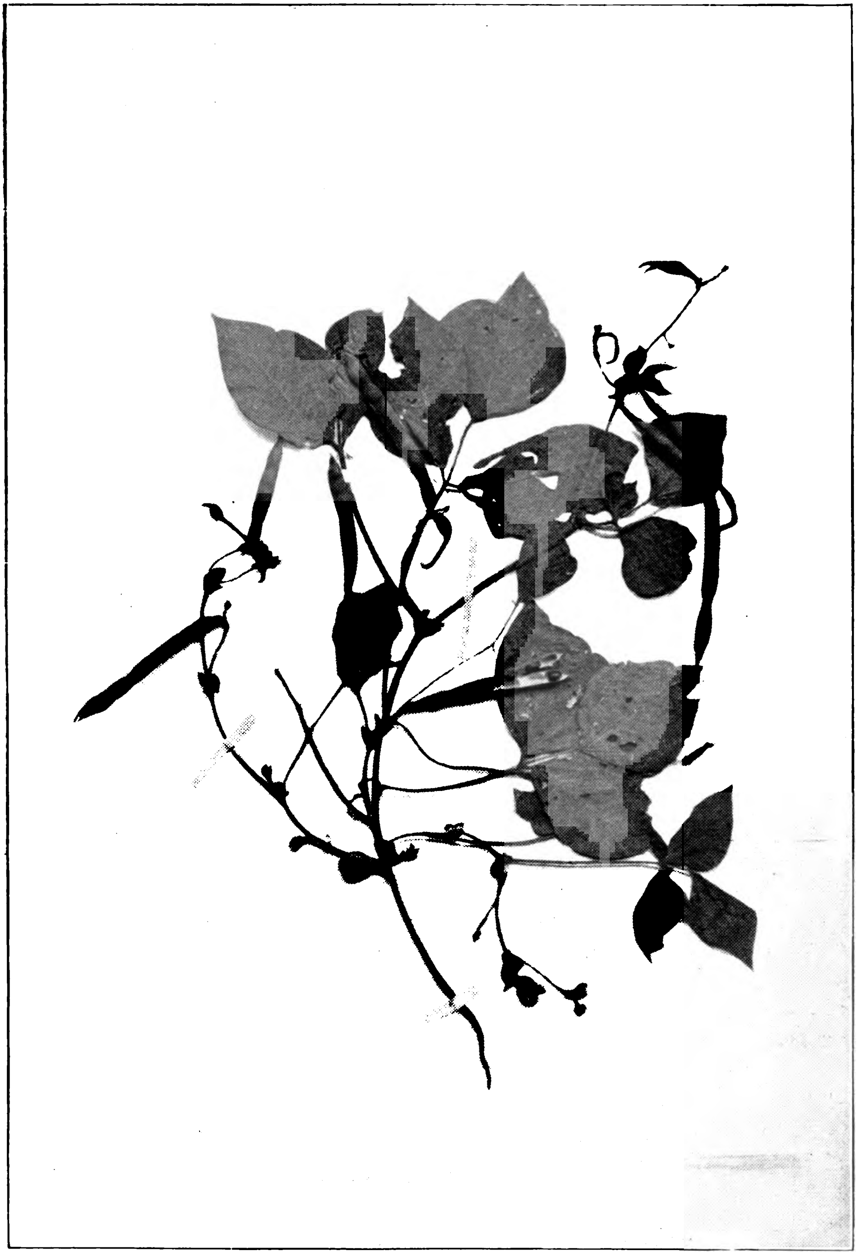
The Chinese use these beans largely in the preparation of "bean sprouts," which are simply seeds that have been soaked in water and allowed to germinate till the young plants are several inches in length. This product is said to be used in making soup. It is difficult to imagine what advantage the young plants possess over the original seeds for such a purpose, unless they impart a different flavor. From an economic standpoint the process is wasteful, as it involves the transformation of albuminoids into various cleavage products and amido-compounds, whose nutritive value is thought to be but slight. Henry[2] refers to the preparation of a kind of vermicelli from this bean, but such a preparation was unknown in San Francisco.

The second form of Phaseolus in use is of a dull red color, rather larger than the previous variety, and more nearly spherical in shape. This is known as the "huang tau" or red bean, designated by the characters 紅荳. Kellner analyzed the seeds of a variety of *P. radiatus*

---

[1] U. S. Dept. Agr., Farmers' Bul. 58, Appendix.

[2] Notes on the Economic Botany of China, p. 13, Shanghai, 1893.



PLANT OF *Phaseolus mungo*.

grown in Japan, which is very probably the same as the one here described, as the two species are by some authors regarded as identical. Harrison and Jenman report the analysis of mungo beans grown in British Guiana.

The composition of the red and green *P. mungo* is shown in Table 12. For purposes of comparison the composition of a green form of *P. mungo* reported by Church, *P. radiatus* reported by Kellner, and "mungo" beans reported by Harrison and Jenman, are also given.

TABLE 12.—*Composition of seed of Phaseolus* spp.

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Phaseolus mungo (green):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	8.83	22.64	21.88	0.76	1.34	48.54	0.00	0.00	4.52	2.85	11.28
Water-free substance	......	24.83	24.00	.83	1.47	53.23	.00	.00	4.95	3.13	11.39
Phaseolus mungo (red):											
Original material....	10.47	21.06	18.19	2.87	.61	48.36	1.65	.00	5.02	3.22	9.61
Water-free substance	......	23.52	20.32	3.20	.68	54.02	1.84	.00	5.61	3.60	10.73
Phaseolus mungo (green): *a*											
Original material....	10.8	22.2	......	......	2.7	......	*b* 54.1		5.8	4.4	......
Water-free substance	......	24.9	......	......	3.0	......	*b* 60.7		6.5	4.9	......
Phaseolus radiatus (red): *c*											
Original material....	12.20	18.30	16.74	1.56	1.42	57.40	*d* 2.02		6.05	2.60	......
Water-free substance	......	20.84	19.06	1.78	1.62	65.38	*d* 2.31		6.89	2.96	......
"Mungo beans:" *e*											
Original material....	14.75	......	20.54	1.52	1.96	*f* 6.71	3.65	.71	3.74	3.39	......
Water-free substance	......	......	24.09	1.78	2.29	7.87	4.28	.83	4.38	3.98	......

a Reported by Church, Food Grains of India. London, Chapman and Hall, 1886, p. 151.
b Carbohydrates by difference.
c Reported by Kellner, Landw. Vers. Stat., 30 (1884), p. 42.
d Determined by difference.
e Reported by Harrison and Jenman, Rpt. Agr. Work Bot. Gard. British Guiana, 1891–92, p. 73.
f The authors also report in the fresh substance 41.23 per cent digestible fiber and 1.80 per cent pectose, gums, etc.

Harrison and Jenman[1] also report analyses of a number of beans whose botanical names were not known. They were called red "mote," "Chinese bean," "kingto," and "octow."

The results of Kellner's analysis, as well as those secured at San Francisco (the red *Phaseolus mungo*), show that the two varieties have essentially the same composition. The analyses also show that about 90 per cent of the protein is in the form of albuminoids. Osborne[2] has studied the proteids of the white-podded adzuki bean, which is presumably the same variety as the one analyzed by Kellner. He found they consisted of phaseolin and a hitherto unknown globulin.

DOLICHOS.

Still another bean, which is largely used by the Chinese of San Francisco, is *Dolichos sesquipedalis.* These seeds are white, with a prominent black ring which surrounds the hilum. The beans weigh about 0.31 gram each. The skin covering the seed is especially tough, but can readily be removed after soaking in water. The beans are most largely used in the form of "bean sprouts" after the removal of this skin. They are known as "mi tau" (眉荳); but this name and its accompanying characters have not been found in any of the books on Chinese botany now accessible to the author. The plant is said to be a native of South America, and was probably recently introduced into China. As shown below, the composition of the dry bean differs but slightly from that of our commonly cultivated variety of beans.

---

[1] Loc. cit.

[2] Jour. Amer. Chem. Soc., 19 (1897), p. 509.

The green pods of this species are also largely used as a snap bean. These are from 50 to 70 centimeters in length, and contain from 10 to 16 seeds. They are more slender than most of our string beans, and slightly ridged along the middle of the two valves. This vegetable is known as "tou kok," and is cultivated by the Chinese along the Sacramento River, arriving in market early in July. It is said that it has come into use among the white residents of the central portion of California, and is considered a valuable variety of string bean. The plant is somewhat tender, and requires a long season for development, but Bailey[1] reports fair success with it in the eastern United States.

Table 13 shows the composition of the seeds and green pods of *D. sesquipedalis* as compared with that of *D. lablab*, cowpeas, and other beans.

TABLE 13.—*Composition of Dolichos and other beans.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Dolichos sesquipedalis (seed):	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*
Original material....	10.98	22.74	17.84	4.90	2.66	45.91	4.27	0.00	2.80	2.86	7.78
Water-free substance	....	25.54	20.04	5.50	2.99	51.57	4.80	.00	3.15	3.21	8.74
Dolichos lablab (seed): *a*											
Original material....	12.1	24.4	......	......	1.5	*b* 57.8			1.2	3.4	......
Water-free substance	....	27.8	......	......	1.7	*b* 65.8			1.4	3.9	......
Cowpeas (*Vigna catjang*) (Average of 13 analyses): *c*											
Original material....	13.0	21.4	......	......	1.4	*b* 56.7			4.1	3.4	......
Water-free substance	....	24.6	......	......	1.61	*b* 65.17			4.71	3.91	......
Dried beans (average of 11 analyses): *d*											
Original material....	12.6	22.5	......	......	1.8	*b* 55.2			4.4	3.5	......
Water-free substance	....	25.74	......	......	2.07	*b* 63.16			5.03	4.0	......
Dolichos sesquipedalis (green pods):											
Original material....	79.92	4.54	3.04	1.50	.53	2.74	1.75	3.26	2.56	1.17	3.53
Water-free substance	....	22.63	15.14	7.49	2.64	13.66	8.72	16.24	12.74	5.81	17.56
String beans (average of 5 analyses): *d*											
Original material....	89.2	2.3	......	......	.3	*b* 5.5			1.9	.8	......
Water-free substance	....	21.30	......	......	2.77	*b* 50.93			17.59	7.41	......

a Reported by Church, Food Grains of India. London: Chapman and Hall, 1886, p. 161.
b Carbohydrates by difference.
c U. S. Dept. Agr., Office of Experiment Stations Bul. 28 (rev. ed.), p. 37.
d Ibid., p. 65.

Harrison and Jenman[2] report the composition of two varieties of *D. lablab*, the crinkled-podded Bonavist bean and the flat-podded

---

[1] New York Cornell Sta. Bul. 67, p. 197.

[2] Rpt. Agr. Work Bot. Gard. British Guiana, 1891-92, p. 70.

Bonavist bean. Their results are not quoted, since the beans were evidently a different species from those purchased in San Francisco.

Both fresh and dry, the Dolichos analyzed in this laboratory compares favorably with the ordinary American beans, and were found on trial to be a satisfactory substitute for these, provided only the tough skin was removed from the dry seeds, which was readily effected. This species seems worthy of a general trial.

VARIOUS WATER PLANTS.

Nelumbium speciosum.—In reviewing the numerous uses of the sacred lotus (p. 17), it was stated that the seeds were an article of food among Asiatic nations, and it is not surprising to find them on sale in San Francisco. Their peculiar shape, the remarkably mature condition of their embryos, and the peculiar form of the embryo itself, all render the seed easy of recognition. Two forms were obtained, the one being somewhat larger and more irregular in shape than the other, but it was impossible to ascertain whether they were the product of plants which differed materially from each other. The smaller and more commonly used of the two forms is known as "pak lin" and is designated by the characters 白蓮; the larger is known as "seung lin" (霜蓮). In all instances the thick outer coating of the seed on sale in San Francisco had been removed, leaving only the inner kernel. Under favorable conditions of temperature and moisture the seeds purchased germinated rapidly, and in the course of a few months from the time of starting produced thrifty plants. Thus far the plants from the two varieties of seeds do not differ materially from each other nor from the commonly cultivated form of lotus. As yet none have produced flowers. The germination of the seeds is somewhat interesting from a botanical point of view and is figured in Pl. II, fig. 4.

The seeds are eaten by the Chinese either raw, boiled, or roasted, being used as we use chestnuts. They are also said to be used in soup, though this seems to be a general term used to designate any mixture that has been boiled. The author was also assured that a form of "arrowroot," i. e., starch, is made from the seed.

The dark green germ is decidedly bitter and must be removed before the seed becomes palatable. Its bitterness has given rise to the Chinese saying, "bitter as the plumule of the lotus seed."

Analyses of the two forms are given in Table 14, p. 41. In the sample of large seed the germs, which form 1.3 per cent of the weight of the entire seed, were removed before analysis, but in the case of the smaller form the entire seed was analyzed.

An inspection of the two analyses shows that the seeds contain a high percentage of nutrients. The protein content is considerably above that of the commonly cultivated cereals, but does not approach that of the leguminous seeds. Nearly all of it is of an albuminoid nature. As might have been expected, starch is the most important nonnitrogenous constituent, though small amounts of other carbohydrates are also present. The starch found in both varieties differs in form from that found in the roots of the lotus.

Euryale ferox.—This is another aquatic, closely related to the lotus both in habit of growth and in botanical affinities. It is designated by the characters 芡實. Like the lotus its seeds form a part of the complex dietary of the Asiatic races.[1] These seeds were occasionally met with in the Chinese stores, but only in a broken and imperfect condition, apparently the result of a mechanical process intended to crack them open. Nevertheless the broken seeds showed such a remarkable resemblance to those of our native *Nuphar polysepalum*, which also furnishes seeds used by the Klamath Indians of Oregon[2] for food, that the author was at once led to suspect their relationship, and a dictionary in the Cantonese dialect, by John Eitel, associates the character used for them with the name given. The seeds are much smaller than those of the lotus, more farinaceous, and their embryos show only a moderate degree of development. The characters used to designate them are quite different from those used for the lotus seeds and the name commonly used is "tsz shat," which, however, does not appear in any of the works descriptive of Chinese botany accessible to the author. They are used principally as an addition to soup, in much the same manner as we use barley, but are also said to be used for the manufacture of starch.

The accompanying analysis (Table 14, p. 41) shows that they possess a food value about equivalent to that of the cereals, the principal constituent being starch, which is present in the form of exceedingly small grains, as shown in Pl. III, fig. 5. Sugars are probably not present, as the small amount reported in the analysis may represent traces of starch which repeated filtration failed to remove from the aqueous extract of the seeds. But little information is accessible regarding adaptability of the plant to the conditions found in the United States. It is already in cultivation in the North Atlantic States and other regions as an ornamental aquatic.

Trapa bispinosa.—The curiously-shaped seeds of this plant, which may be aptly compared with the head and horns of a cow, are familiar objects in the Chinese bazaars, where they are sold as curiosities. The regular Chinese merchant, however, is quite sure to have them in stock during the spring months, and they are sold by him as an article of diet. In the bazaars they are known as the "horn chestnut." The Chinese name is "ling ko" (菱角). This is also the name by which they are known in the Chinese classics, as the seeds are sometimes included among the five food grains of China. The seeds do not keep well, and those which find their way into the bazaars are often entirely decayed within.

The fresh seeds have a kernel which, in consistency and taste, resemble the chestnut. They will germinate readily if placed in a vessel of water and produce the curious floating foliage characteristic of this genus of plants. (See Pl. II, fig. 1, and Pl. III, fig. 4.)

---

[1] Bretschneider, Jour. China Branch Roy. Asiatic Soc., 25 (1890), p. 218.

[2] Coville, Contrib. U. S. Nat. Herb., 5 (1897), No. 2, p. 96.

Authors are at variance as to the correct name of the plant producing these seeds. Forbes and Hemsley[1] regard it as one of the forms of the more widely known European *T. natans* inasmuch as they find many intermediate forms between the Chinese and the European species. By other writers the plant is variously designated as *T. bispinosa*, *T. bicornis*, *T. cochinchinensis*, and *T. incisa*. The plants to which these terms are applied are probably identical. As a means of distinguishing it from *T. natans*, from which the seeds analyzed by the author certainly differ, the name *T. bispinosa* has been adopted in this report.

The composition of the two sorts of Nelumbium seed, of *Euryale ferox*, and *Trapa bispinosa* are shown in the following table:

TABLE 14.—*Composition of seeds of various water plants.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Nelumbium speciosum (large form):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material ...	8.72	16.64	15.47	1.17	2.44	51.64	4.09	2.41	3.15	3.03	7.88
Water-free substance	....	18.23	16.95	1.28	2.67	56.57	4.48	2.64	3.45	3.32	8.63
Nelumbium speciosum (smaller form):											
Original material ...	9.40	17.73	17.64	.09	2.96	40.63	9.55	......	2.95	4.15	12.63
Water-free substance	....	19.57	19.46	.10	3.26	44.84	10.54	......	3.26	4.58	13.94
Euryale ferox:											
Original material ...	13.10	9.79	9.79	....	4.90	68.07	1.59	......	.83	.51	1.18
Water-free substance	....	11.26	11.26	....	5.64	78.33	1.83	......	.96	.62	1.36
Trapa bispinosa:											
Original material ...	10.59	10.88	10.42	.46	.65	60.39	....	3.95	1.41	2.57	9.56
Water-free substance	....	12.16	11.65	.51	.73	67.53	....	4.42	1.58	2.87	10.70

The analysis here reported of the seeds of *Trapa bispinosa* is not typical as regards water content, since the seeds used had been kept for a considerable time before they were analyzed and were unusually dry. The average weight of the seeds is about 4 grams and in those used the kernel constituted about 64.3 per cent of the total. Their food value is slightly less than that of the seeds of the Euryale, but, judged solely by their composition, they nevertheless contain a high percentage of nutritive material.

CHINESE MILLET.

Though this grain was not found on sale in San Francisco, it has a widely extended use in China and Japan. The sample analyzed in this laboratory was given to the author by Professor Fryer, who states that it is more especially used in the northern part of China. He considers it a very valuable article of diet and believes this plant should be introduced into cultivation in the United States. The species (presumably Panicum) to which the sample belongs can not be determined until plants have been grown from it. Several species of Panicum and closely related genera are in cultivation in China. Church reports the composition of a considerable number of millets used as food in India, and discusses their food value at some length.

---

[1] Index Floræ Sinensis, 1887, p. 311.

The composition of the sample is shown in the following table:

TABLE 15.—*Composition of millet.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Panicum sp.:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	11.60	8.56	8.08	0.48	2.64	67.47	0.06	0.00	3.32	1.79	4.56
Water-free substance	....	9.68	9.14	.54	2.94	76.32	.07	.00	3.75	2.02	5.16
Panicum italicum: a											
Original material....	12.04	7.40	6.64	.76	3.87	45.73	*b*28.48		1.37	1.11	......
Water-free substance	....	8.43	7.56	.87	4.40	51.99	*b*32.38		1.54	1.26	......
Panicum miliaceum: c											
Original material....	12.0	12.6	....	....	3.6	*d*69.4			1.0	1.4	......
Water-free substance	....	14.3	....	....	4.1	*d*78.9			1.1	1.6	......

a Reported by Kellner, Landw. Vers. Stat., 30 (1884), p. 42.
b Determined by difference.
c Reported by Church, loc. cit., p. 43.
d Carbohydrates by difference.

For the sake of comparison, two analyses, one of a Japanese-grown sample, the other of a sample grown in India,[1] are included in the table above. All three analyses confirm the statement that in composition this grain ranks with the more commonly cultivated cereals. It is possible that it might find an important place among our cultivated grains.

FRUITS, NUTS, AND FLOWERS.

Nephelium litchi.—This tree furnishes the well known "li chee" or "lai chi" nuts (荔枝), which are so frequently used as tokens of good will by the Chinese laundryman or vegetable peddler about the time of their New Year. The edible portion of the li chee nut is really the fleshy aril which immediately surrounds the smooth brown seed and is in turn surrounded by the thin warty shell of the fruit itself. The nuts may be obtained in the dry form and also preserved with sugar in cans. In the sample analyzed the aril formed 46 per cent of the weight of the dry seed, but these figures can scarcely be considered typical as the fruits were kept for some months before being used. The composition of "li chee" nuts is shown in Table 16, p. 45. As might be expected from their sweet taste, sugar, especially reducing sugar, is their most important constituent. Other nutritive substances are present in small amounts.

The tree has been a favorite subject for greenhouse treatment in temperate climates for many years and is also reported to tolerate the climatic conditions found in southern California in a satisfactory manner.

---

[1] Food Grains of India, pp. 34–59. London, Chapman & Hall, 1886.

Nephelium longan.—The fruit of this tree, designated by the characters 龍眼圓, differs from that of *N. litchi* in being somewhat smaller and smooth, otherwise it closely resembles the "li chee" nut. However, it is considered inferior to the li chee by the Chinese. The sample was kept for some time before analysis, and hence the figures for water content and those based on this determination are scarcely typical. The aril formed 40 per cent of the entire seed. Its composition is shown in Table 16, p. 45. In composition it does not differ greatly from the "li chee" save in the relative amounts of reducing and cane sugars present.

Zizyphus jujuba.—This is the Indian fig largely cultivated in tropical Asia, Africa, and Australia, and is designated by the characters 紅棗. The dried fruits are used by the Chinese in the same manner as the two mentioned above and are also well liked by Europeans. The European species (*Z. vulgaris*), is, however, better known and furnishes the important constituent of the jujube paste of the confectioners' shops. The composition of the fruit of *Z. jujuba* is shown in Table 16, p. 45.

Canarium album.—The so-called Chinese olive is the fruit of several species of Canarium, *C. album* and *C. pimela* being probably the two species whose fruit is chiefly used. The Chinese olive is a fleshy drupe 3 to 6 centimeters in length, which contains a hard, triangular, sharp-pointed seed. (See Pl. II, fig. 6.) Within this are found one or more oily kernels. The fruits, known as "pak lam" (白欖), are found on sale in San Francisco, either green or salted and dried. They are also sold in the form of certain highly flavored preparations which are not generally acceptable to the American palate. The flesh of the fresh, yellowish-green fruit, like that of the true olive, is somewhat acrid and disagreeable, and requires special treatment before it can be made palatable. Smith[1] says that the fruits are often preserved in salt, and are also added to wine to moderate or counteract its effect.

The sample analyzed by the author (see Table 16, p. 45) represents the fresh pulp of the fruit. The most important constituent is fat, which forms nearly one-fourth of the total nutritive material.

The kernel of the seed of one variety of Chinese olive is also sold under the name of "lam yen" (欖仁). The peculiar form of these seeds is shown in Pl. II, fig. 7. They are covered with a thick, reddish skin, but have the consistency and general characteristics of many other oily seeds. Microscopical examination showed the presence of well-formed aleurone grains, the crystalloids of which are remarkably well developed. The analysis of the seeds (reported in Table 16) shows that in composition they closely resemble walnuts and similar nuts. The fat present consists of a yellow fluid oil, which absorbs 83.17 per cent of iodin. When fresh, the kernels are as palatable as walnuts and other common nuts. Little is known as to the adaptability of Chinese olive trees to other than tropical climates. It is questionable whether many portions of the United States would furnish the conditions favorable to their growth.

---

[1] Contributions Toward the Materia Medica and Natural History of China, p. 50. Shanghai, 1871.

Ginkgo biloba (*Salisburia adiantifolia*).—A detailed account of this tree seems scarcely necessary, since it is well known—by nurserymen, at least—throughout the United States, though its merits as an ornamental tree are by no means fully appreciated. The trees grow readily and have fruited abundantly as far north as Washington, D. C. The white, thin-shelled nuts (Pl. II, fig. 2), known as "pak ko" or "gink ko" (白菓), are eaten by the Chinese, being first roasted or boiled, like chestnuts. They are somewhat acrid in the fresh state, and have a very disagreeable odor. When roasted or boiled, their flavor is peculiar. They are said by Hanbury,[1] Smith, and others to assist in digestion and to be eaten after meals for this purpose by the Chinese.

The pulp surrounding the seed of the fresh fruit has been examined by Bechamp,[2] who obtained from it the entire series of homologous fatty acids, from formic acid to caprylic acid. He also noted the occurrence of starch in the endosperm, though a complete analysis of the seed does not seem to have been made. The nuts found in San Francisco were evidently unusually dry. The analysis (Table 16, p. 45) shows that by far their most important constituent is starch. This is somewhat remarkable, as it is the only instance of which record has been found in which starch has been observed in any considerable quantity in the seed of a coniferous plant.

Some experiments were conducted by a student in this laboratory to determine whether the seed contained a digestive ferment. Samples of fish flesh were treated under suitable conditions with a decoction of the seeds, but no digestive action was observed.

Hemerocallis fulva.—Still another and very unusual vegetable substance largely used as a flavoring ingredient by the Chinese consists of the dried flowers of *H. fulva*, the day lily of American gardens. This substance is known as "kam cham t'soi," or the "gold-needle vegetable," and is designated by the characters 金針菜. It is reported by Bretschneider[3] to be in common use. As noted on page 20, Davy[4] refers to the use of the flowers of *Lilium bulbiferum* and *H. graminea* as food by the Chinese. The composition of flowers of *H. fulva* is shown in Table 16, p. 45.

---

[1] Notes on Chinese Materia Medica, Scientific Papers, 1876.

[2] Compt. Rend. Acad Sci. Paris, 58 (1864), p. 135; Ann. Chim. et Phys., 4. ser., 1 (1864), p. 288.

[3] Jour. China Branch Roy. Asiatic Soc., 15 (1880), p. 110.

[4] Erythea, 6 (1898), p. 25.

When judged by their composition, flowers of *H. fulva* are seen to possess a rather high food value. They are used, however, rather as a condiment than as an article of diet.

The composition of the fruit of *Nephelium litchi* ("li chee" nuts), *N. longan*, *Zizyphus jujuba*, *Canarium album* (Chinese olive), pulp and seeds; *Ginkgo biloba*, "gink ko" nuts, and the dried flowers of *Hemerocallis fulva* are shown in the following table:

TABLE 16.—*Composition of fruits, nuts, and flowers.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Nephelium litchi (aril):	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Original material....	14.94	2.91	....	......	1.44	....	4.47	66.58	......	2.21	7.45
Water-free substance	....	3.43	....	......	1.69	....	5.25	78.27	......	2.60	8.75
Nephelium longan (aril):											
Original material....	10.94	5.01	....	......	1.04	....	37.50	27.34	......	2.31	15.86
Water-free substance	....	5.63	....	......	1.17	....	42.11	30.70	......	2.59	17.80
Zizyphus jujuba (pulp):											
Original material....	13.44	2.93	....	......	....	....	13.06	42.19	......	1.73	26.65
Water-free substance	....	3.39	....	......	....	....	15.09	48.74	......	2.00	30.78
Canarium album (pulp):											
Original material....	73.22	.77	.61	.15	6.55	3.16	.53	1.95	4.15	1.50	8.17
Water-free substance	....	2.86	2.28	.57	24.46	11.79	1.99	7.26	15.48	5.61	30.53
Canarium sp. (seeds):											
Original material....	5.71	16.44	16.44	.00	59.57	.00	.92	.00	3.20	5.16	9.00
Water-free substance	....	17.44	17.44	.00	63.18	.00	.97	.00	3.39	5.47	9.54
Ginkgo biloba (seeds):											
Original material....	47.34	5.90	5.18	.72	.81	33.90	3.58	.00	.88	2.00	5.58
Water-free substance	....	11.21	9.84	1.37	1.53	64.34	6.79	.00	1.68	3.81	10.60
Hemerocallis fulva (dried flowers):											
Original material....	15.70	10.11	....	......	3.42	5.98	30.51	12.40	8.74	3.64	9.50
Water-free substance	....	11.99	....	......	4.06	7.09	36.19	14.71	10.37	4.32	11.27

FUNGI AND ALGÆ.

Russula sp.—Several species of fungi are largely used in the Chinese dietary, and when dried are standard articles of trade in San Francisco. The one most largely used is a white-spored species of Agaricini, probably of the genus Russula. It is designated by the characters 冬瓜. It is easily distinguished from the American edible species by the tough, coriaceous character of both pileus and stipe, the latter being short and eccentrically attached. In color it is yellow, except the top of the pileus, which is brown or purple. At least two other species of this group are on sale in San Francisco, but these are delicacies rather than staple articles of diet, some of them retailing as high as $2 per pound.

The composition of the Russula is shown in Table 17, p. 47, and presents some interesting features. The figures for protein are far below those which have been assigned to edible fungi of this type, being only one-third to one-half the amounts reported for *Agaricus campestris*, species of Tuber,[1] etc. Of the protein, about four-fifths is in the form of albuminoids.

The exact nature of the large amount of carbohydrates present is unknown, and would form an interesting subject for investigation.

Peziza auricula.—Most of the notes of the earlier writers on Chinese botany contain references to the use of a peculiar mushroom which grows on decaying wood. This is a species of Peziza, probably *P. auricula.* It is designated as "mo eh" (Loureiro) or "mu ery" (木耳), by Henry, the English equivalent of which would be "wood ears," and is used in large quantities in San Francisco. The composition of the fungus is shown in Table 17, p. 47. The protein content of this fungus is remarkably low; sugars seem to be entirely absent, but some starch-like substance of an unknown nature forms more than one-third of the total weight. The fungus is decidedly tough and woody, and apparently possesses no especially valuable food characteristics.

Nostoc commune flagelliforme.—Of the algæ, one form which occurs in black tangled masses resembling horsehair is largely used by the Chinese. This was identified by Prof. W. A. Setchell as *Nostoc commune flagelliforme.* It is designated by the characters 髮菜. The use of this plant as an article of food does not seem to have been heretofore reported. Treated with boiling water, it forms a gelatinous mass, and is used as a thickening medium for various culinary preparations, one of the most esteemed being a combination of this vegetable with dried shrimps. The analysis shows a high percentage of protein, but only insignificant amounts of other food constituents.

Other forms of algæ which were identified by Professor Setchell are *Porphyra perforate*, and *P. nereocystis*, both of which are collected in large amounts at the Bay of Monterey, and two other species of the same genus, presumably *P. suborbiculata* and *P. tenera*, which are cultivated in Japan.

Species of Porphyra are used in considerable quantities for food by the natives in southeastern Alaska. The algæ are collected, pressed together and dried, and when used, are shaved into warm water and boiled to a thick porridge.[2] A sample of this algæ analyzed in the chemical laboratory of the Connecticut (Storrs) Station, had the composition reported in Table 17, p. 47.

The composition of the fungi and algæ analyzed, together with analyses of fungi quoted for purposes of comparison, is reported in the following table:

---

[1] König, Chemie der menschlichen Nahrungs- und Genussmittel, 3. ed., I, p. 747.

[2] This information is furnished by W. H. Evans, Ph. D., of this Department.

TABLE 17.—*Composition of fungi and algæ.*

	Water.	Protein.	Albuminoids.	Amids (by difference).	Fat.	Starch.	Cane sugar.	Reducing sugars.	Crude fiber.	Ash.	Undetermined.
Russula sp.:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pr. ct.*	*Per ct.*	*Per ct.*	*Pr. ct.*	*Pr. ct.*	*Per ct.*	*Pr. ct.*
Original material ...	8.40	15.42	12.87	2.55	2.56	21.41	.00	6.63	12.97	4.54	28.07
Water-free substance	....	16.83	14.05	2.78	2.79	23.37	.00	7.24	14.16	4.96	30.64
Peziza auricula:											
Original material ..	10.38	4.14	2.93	1.21	1.36	34.68	.00	.00	27.04	2.11	20.29
Water-free substance	....	4.62	3.27	1.35	1.52	38.69	.00	.00	30.17	2.35	22.64
Agaricus campestris culinaris: [a]											
Original material ...	92.84	3.40	......	......	.07	......	......	......	.54	.76	......
Water-free substance	....	47.47	......	......	.96	......	......	......	7.55	10.67	......
Morchella esculenta: [b]											
Original material ...	89.54	[c]3.06	......	......	.50	[d]1.60			.91	1.08	......
Water-free substance	....	29.8	......	......	4.80	[d]15.3			8.7	10.4	......
Nostoc commune flagelliforme:											
Original material....	10.58	20.93	......	......	1.19	......	.00	.00	4.07	7.50	......
Water-free substance	....	23.41	......	......	1.33	......	......	......	4.55	8.39	......
Porphyra laciniata: [e]											
Original material....	21.85	25.70	......	......	.17	[f]37.68				14.60	......
Water-free substance	....	32.88	......	......	.22	[f]48.22				18.68	......

[a] Reported by Dahlen, Landw. Jahrb., 4 (1874), p. 639.
[b] Reported by Mendell, Amer. Jour. Physiol., 1 (1898), p. 225.
[c] Total nitrogen 0.49, albuminoid nitrogen 0.37, and nonalbuminoid nitrogen 0.12 per cent.
[d] Approximation.
[e] Unpublished analysis from Chem. Lab. of Connecticut (Storrs) Station.
[f] Determined by difference.

MISCELLANEOUS SUBSTANCES.

In addition to the above materials there are a number of others which are used to a greater or less extent. The following were examined. Although they did not seem important enough to demand an analysis they are worthy of at least a passing notice.

The roots of an aroid, which seems to be *Amorphophallus rivieri*, are frequently observed on the vegetable stands in the Chinese quarter of San Francisco. Plants grown from them at Berkeley have thus far failed to produce flowers, so that their absolute identification is as yet impossible. Henry,[1] however, refers to the use of the plant by the Chinese, but uses a character to designate it which differs from that used in San Francisco. The roots, known as "kai chau u" (鷄爪芋), are exceedingly acrid, and the directions given when the samples were purchased were to boil for several days before using. They are said to possess medicinal or at least restorative properties, the roots being used especially by persons who need a light diet. The roots sold in San Francisco, which are figured in Pl. III, fig. 6, are of interest on account of the peculiar compound starch grains which they contain. The roots of the closely related *Conophallus konjak*, which are largely used by the Japanese in much the same manner, have already been analyzed by Kellner,[2] who believed them to consist largely of starch. The later investigations of Tsuji[1] have shown that the carbohydrate material consists quite largely of mannane and contains no starch.

---

[1] Notes on the Economic Botany of China, p. 35. Shanghai, 1893.
[2] Landw. Ver. Stat., 30 (1884), p. 42.

The rhizomes of common ginger, *Zingiber officinale*, are largely used by the Chinese in California and may be obtained in a fresh condition throughout the year.

Among green vegetables the common purslane, *Portulaca oleracea*, is sometimes seen on the vegetable stands, but it is not extensively used. Purslane is used to some extent as a pot herb in American households. Its suitability for this purpose has been pointed out by Coville.[2]

According to an analysis reported by Huston,[3] purslane has the following percentage composition: Water, 86.56; protein, 1.81; fat, 0.50; nitrogen-free extract, 6.49; crude fiber, 2.12; ash, 2.23. It is noted that the ash content is unusually high.

The young shoots of a bamboo, probably a species of Arundinaria, are also sold, either pickled in brine or canned.

Of seeds, those of the common watermelon are very commonly eaten, usually raw. Two varieties of sesame seed, one black, the other white, are used in soup as barley is used in American households. A peculiar variety of the almond and another of the chestnut are also imported from China.

Among fruits, dried persimmons are often met with. The persimmon seems to be well adapted to this method of preservation. The seeds of *Areca catechu*, or betel palm, are often sold on the street corners in the Chinese quarters of San Francisco. A combination of slices of this nut with lime and the leaves of a species of piper, as used by the betel chewer, may also be obtained. However, they could not be identified.

The Chinese drug stores also furnish some curious objects of a vegetable nature. Among these were identified, chiefly through the report of Hanbury[4] on the Chinese materia medica, the fruit stalks of *Hovenia dulcis*, the seeds of *Torreya nucifera*, *Quisqualis indica*, *Momordica (Muricia) cochinchinensis*, *Terminalia chebula*, *Sterculia platanifolia*, *Ipomœa hederacea*, *Chalmougra* sp., *Melia* sp., and the fruits of a species of *Gardenia*.

---

[1] Imp. Univ. Col. Agr. [Tokyo] Bul., Vol. 2 (1894), p. 103.

[2] U. S. Dept. Agr., Yearbook 1895, p. 213.

[3] Indiana Sta. Rept. 1897, p. 16.

[4] Scientific Papers, 1876, pp. 228–254.

BULLETIN NO. 85. 353.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

A REPORT OF INVESTIGATIONS

ON

The Digestibility and Nutritive Value of Bread.

BY

CHAS. D. WOODS,
DIRECTOR,

AND

L. H. MERRILL,
CHEMIST,

MAINE AGRICULTURAL EXPERIMENT STATION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., April 20, 1900.

Sir: I have the honor to transmit herewith a report of investigations on the digestibility and nutritive value of bread, conducted at the Maine Agricultural Experiment Station by Chas. D. Woods, director of the station, and L. H. Merrill, the station chemist, under the supervision of Prof. W. O. Atwater, special agent in charge of nutrition investigations, in accordance with instructions given by the Director of this Office.

In connection with the nutrition investigations under the general direction of this Office, studies on bread, with special reference to digestibility, methods of making and baking, and other factors affecting its nutritive value, have been carried on at several institutions by a number of investigators, Professor Woods, as special agent of the Department, having had the immediate direction of this work. The investigations herein reported are a part of this series and have to do with the digestibility of various kinds of bread when eaten alone and when forming the principal part of a simple mixed diet, the determination of the amount of metabolic nitrogen in feces, the digestibility of bread of different sorts by artificial methods, the comparative value of bread made with skim milk and with water, and the losses in bread making. On some of these subjects the work is being continued and the data here given constitute a progress report.

The report is transmitted with the recommendation that it be published as Bulletin No. 85 of this Office.

Respectfully,
A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
Introduction 7
  Analytical methods 8
  Heat of combustion 8
  Composition of food materials 9
  Composition of feces 10
Experiments on the digestibility of bread 11
  Digestion experiments with men 11
    Experiments with bread alone 13
    Experiments with mixed diet, largely bread 15
  Metabolic products in feces 33
    Treatment of feces with pepsin solution 34
    Treatment of feces with ether, alcohol, hot water, and cold limewater 35
    Metabolic nitrogen in the feces on a carbohydrate diet and during fasting 39
  Artificial digestion of bread with pepsin 42
  Comparison of coefficients of digestibility of protein in bread as determined by different methods 43
Skim milk versus water in bread making 45
  The digestibility in pepsin solution of bread made with skim milk and with water 48
Losses in bread making 49

DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD.

INTRODUCTION.

Wheat, in one or another of its many preparations for the table, forms a very large factor in the nutrition of the American people. In connection with the investigations of the food and nutrition of man which have been carried on in cooperation with the Office of Experiment Stations of the U. S. Department of Agriculture for the past few years, the Maine Experiment Station has been investigating the digestibility and nutritive value of bread. While this subject has been investigated from time to time, particularly in Europe, with very interesting and valuable results, few of these results are applicable to the conditions common in this country. The European investigations have been made with flours different from those in common use in the United States and the breads have been made by methods not commonly adopted by bakers in this country.

A considerable number of foreign investigations on the digestibility of bread or other foods made from the cereal grains and experiments on bread and other similar diets in which the balance of income or outgo of nitrogen was determined have been summarized in previous publications of this Office.[1] A number of special studies of bread have been made in connection with the nutrition investigations conducted under the auspices of the Office of Experiment Stations and reported in earlier bulletins.[2] The studies here reported are only part of an investigation undertaken with the hope of accumulating data which shall serve to answer the numerous questions arising as to the effects of milling upon the nutritive value of the resulting flours. The purpose of this bulletin is simply to put on record the results of some of the investigations. Discussion is reserved until the results of the more extended investigations now being carried on shall be available.

The work here reported includes (1) 24 digestion experiments with men, in which bread formed all or the main part of the diet; (2) 24 experiments upon the artificial digestion of bread with pepsin; (3) a study of the income and outgo of nitrogen in 26 experiments with men; (4) the estimation of metabolic nitrogen in the feces from the 24 digestion experiments with men; (5) a study of metabolic nitrogen in feces in a period with a diet of carbohydrates alone, in a period of fasting, and in a period of partial fasting; (6) an investigation of the nutritive value of bread made with skim milk as compared with that made with water, and (7) experiments on the losses of material in baking bread.

---

[1] U. S. Dept. Agr., Office of Experiment Stations, Buls. 21 and 45.

[2] U. S. Dept. Agr., Office of Experiment Stations, Buls. 31, 35, 52, 53, and 67.

ANALYTICAL METHODS.

All food materials used in the investigation were sampled at the time of use and all the feces were collected, dried, and analyzed. The methods of analysis were mainly those of the Association of Official Agricultural Chemists.[1] In determining the ash in flour and bread, it was found necessary to extract the charred parts with hot water before the incineration could be completed. In preparing the bread for analysis, it was sliced and dried at a temperature of about 60°. The feces were dried at a like temperature. The determination of ether extract in the feces was accomplished with considerable difficulty and the results are not regarded as wholly satisfactory. Composite samples of milk used during each experiment were taken for analysis. In the first four experiments in which no food other than bread was eaten, a small amount of beef tea was allowed each subject, but the nitrogen thus taken was not determined, as it was believed that it would be wholly absorbed from the intestines and appear largely unchanged in the urine.[2]

HEAT OF COMBUSTION.

The determinations of the heat of combustion of food, feces, and urine were made by burning samples of dried material in the bomb calorimeter in the usual manner. The milk and urine were prepared for combustion in the following manner: A weighed absorption block[3] of cellulose, previously dried for two days over sulphuric acid, was placed in a platinum capsule and saturated with a known amount of milk or urine. The capsule and block were then placed in a drying oven and dried at a temperature not exceeding 70° C., after which the absorption block was again saturated with a known amount of substance and again dried. The combustion was made in the usual manner, correction being made for the heat given off by the combustion of the absorption block itself. This latter factor was previously ascertained by determining the heat of combustion of the cellulose absorption blocks.

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 66.

[3] Described by Kellner, Landw. Vers. Stat., 47 (1896) p. 297.

COMPOSITION OF FOOD MATERIALS.

The different kinds of bread were handmade from ordinary wheat flour, so-called Graham flour, true Graham flour, and entire wheat flour. The milk and butter were the ordinary dairy products of good quality. The analyses of the food materials are summarized in Tables 1 and 2:

TABLE 1.—*Percentage composition and heat of combustion per gram of fresh food materials.*

Laboratory number.	Number of experiment.	Material.	Water.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion. Determined.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
6001	123	White bread	36.06	1.40	8.78	1.73	52.73	0.70	2,841
6002	124	.....do	34.48	1.39	8.68	1.68	54.42	.74	2,938
6003	125	.....do	34.68	1.39	8.68	1.91	53.43	1.30	2,926
6004	126	.....do	34.10	1.40	8.73	1.74	54.04	1.39	2,938
6005	127	.....do	34.07	1.36	8.51	2.98	52.46	1.98	2,943
6006	128	.....do	33.35	1.37	8.59	2.23	53.90	1.93	2,960
6007	129, 130	.....do	38.51	1.52	9.50	.81	50.42	.76	2,698
6034	131	Graham bread	28.17	1.62	10.11	1.28	57.42	3.02	3,032
6035	132	.....do	41.92	1.32	8.24	1.05	46.85	1.94	2,476
6036	133	.....do	51.81	1.08	6.76	.90	38.61	1.92	2,049
6037	134	.....do	42.39	1.26	7.86	1.16	46.55	2.04	2,456
6047	135	Entire wheat bread	42.22	1.35	8.45	.42	47.07	1.84	2,467
6048	136	.....do	40.11	1.40	8.77	.42	48.79	1.91	2,560
6049	137	.....do	40.39	1.39	8.67	.43	48.62	1.89	2,558
6064	138	White bread	38.04	1.45	9.07	1.95	49.65	1.29	2,818
6065	139	.....do	37.43	1.47	9.19	1.87	50.22	1.29	2,840
6077	140	.....do	37.35	1.44	8.97	2.39	49.94	1.35	2,845
6078	141	.....do	37.61	1.43	8.96	2.29	49.65	1.49	2,829
6086	142	Entire wheat bread	38.34	1.51	9.43	2.62	48.21	1.40	2,859
6087	143	.....do	38.83	1.49	9.29	2.68	47.83	1.37	2,829
6097	144	Graham bread	42.09	1.14	7.15	2.97	46.21	1.58	2,639
6098	145	.....do	41.90	1.19	7.42	2.75	46.46	1.47	2,648
6120	146	White bread	38.14	1.45	9.04	1.34	50.33	1.15	2,809
6008	127	Milk	86.87	.49	3.06	3.70	5.60	.77	792
6009	128	.....do	86.87	.55	3.44	4.00	4.93	.76	799
6010	129	.....do	86.87	.53	3.31	4.00	5.02	.80	780
6011	130	.....do	86.52	.53	3.31	4.25	5.16	.76	807
6032	131–134	.....do	86.45	.55	3.44	4.00	5.38	.73	823
6033	131–134	.....do	86.07	.53	3.31	3.95	5.93	.74	819
6046	135–137	.....do	86.39	.55	3.44	4.15	5.30	.72	820
6057	135–137	.....do	86.43	.55	3.44	4.00	5.34	.79	812
6066	138, 139	.....do	87.20	.56	3.50	4.20	4.41	.69	728
6068	138, 139	.....do	86.81	.59	3.69	4.20	4.60	.70	799
6071	138, 139	.....do	86.72	.56	3.50	4.20	4.88	.70	752
6079	140, 141	.....do	86.38	.53	3.31	4.25	5.56	.50	797
6080	140, 141	.....do	86.84	.57	3.56	3.98	5.08	.54	774
6088	142, 143	.....do	85.51	.59	3.69	5.00	5.15	.65	902
6089	142, 143	.....do	86.02	.57	3.56	5.00	4.84	.58	857
6099	144, 145	.....do	86.07	.58	3.63	4.60	4.95	.75	888
6100	144, 145	.....do	86.88	.54	3.38	4.60	4.52	.62	814
6121	146	.....do	85.55	.58	3.63	5.40	4.67	.75	898
6067	138, 139	Butter	9.93	.21	1.31	85.00	....	3.76	a 7,977
6081	140, 141	.....do	11.44	.22	1.38	82.45	....	4.73	a 7,744
6090	142, 143	.....do	13.04	.13	.81	80.19	....	5.96	a 7,502
6107	144, 145	.....do	13.26	.18	1.13	79.12	....	6.48	a 7,420
6122	146	....	13.20	.20	1.25	81.48	....	4.07	a 7,646

a Computed, using the factors 5.5 for protein and 9.3 for fat.

TABLE 2.—*Percentage composition and heat of combustion per gram of dry matter of different breads eaten.*

Laboratory number.	Number of experiment.	Material.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion. Determined.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
6001	123	White bread	2.20	13.73	2.70	82.48	1.09	4,444
6002	124	.....do	2.12	13.25	2.57	83.05	1.13	4,484
6003	125	.....do	2.13	13.29	2.92	81.80	1.99	4,480
6004	126	.....do	2.12	13.24	2.64	82.01	2.11	4,457
6005	127	.....do	2.07	12.91	4.51	79.57	3.01	4,463
6006	128	.....do	2.06	12.89	3.34	80.88	2.89	4,441
6007	129, 130	.....do	2.47	15.46	1.31	82.00	1.23	4,339
6034	131	Graham bread	2.25	14.07	1.79	79.94	4.20	4,221
6035	132	.....do	2.27	14.20	1.81	80.66	3.33	4,263
6036	133	.....do	2.24	14.03	1.85	80.14	3.98	4,253
6037	134	.....do	2.18	13.64	2.01	80.80	3.55	4,264
6047	135	Entire wheat bread	2.34	14.61	.73	81.47	3.19	4,281
6048	136	.....do	2.34	14.61	.73	81.47	3.19	4,275
6049	137	.....do	2.34	14.61	.73	81.47	3.19	4,266
6064	138	White bread	2.34	14.64	3.15	80.13	2.08	4,548
6065	139	.....do	2.35	14.68	2.99	80.26	2.07	4,538
6077	140	.....do	2.29	14.32	3.82	79.70	2.16	4,541
6078	141	.....do	2.30	14.36	3.67	79.58	2.39	4,533
6086	142	Entire wheat bread	2.45	15.30	4.24	78.17	2.29	4,636
6087	143	.....do	2.43	15.18	4.38	78.20	2.24	4,625
6097	144	Graham bread	1.98	12.35	5.14	79.77	2.74	4,662
6098	145	.....do	2.04	12.77	4.73	79.96	2.54	4,557
6120	146	White bread	2.34	14.61	2.17	81.36	1.86	4,816

COMPOSITION OF FECES.

As stated above, the usual methods were followed in the analyses of the feces.

The composition of the feces in the various digestion experiments reported in this bulletin is shown in Table 3. The results are calculated to the water-free basis, since the amount of water in the fresh feces has no bearing upon the results of the digestion experiments.

TABLE 3.—*Percentage composition and heat of combustion per gram of dry matter of feces.*

Laboratory number.	Number of experiment.	Material.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion. Determined.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
6020	123	Feces	5.35	33.47	12.86	37.26	16.41	6,074
6021	124	.....do	8.57	53.67	17.70	18.29	10.34	5,950
6022	125	.....do	5.96	37.22	14.25	28.32	20.21	5,361
6023	126	.....do	8.83	55.16	14.69	18.37	11.78	5,900
6024	127	.....do	6.35	39.69	20.04	25.89	14.38	5,800
6025	128	.....do	4.82	30.14	17.38	29.97	22.51	5,611
6026	129	.....do	5.27	32.91	12.51	32.86	21.72	5,563
6027	130	.....do	5.27	32.93	23.62	22.46	20.99	5,424
6042	131	.....do	4.11	25.69	7.74	49.15	17.42	5,220
6043	132	.....do	4.24	26.52	9.95	44.53	19.00	4,613
6044	133	.....do	3.74	23.40	7.95	48.19	20.46	4,890
6045	134	.....do	4.07	25.44	8.54	44.56	21.46	4,654
6051	135	.....do	5.10	31.88	12.86	35.35	19.91	5,400
6052	135	.....do	4.10	25.64	8.52	39.42	26.42	4,340
6053	136	.....do	4.47	27.91	10.25	38.18	23.66	4,736
6069	137	.....do	4.40	27.52	16.87	31.70	23.91	5,753
6070	138	.....do	4.87	30.45	27.42	25.40	16.73	6,019
6082	139	.....do	3.94	24.65	12.95	36.17	26.23	5,604
6083	140	.....do	4.11	25.70	11.91	39.55	22.84	6,082
6091	141	.....do	4.43	27.68	15.52	38.43	18.37	5,667
6092	142	.....do	4.71	29.46	14.81	40.71	15.02	5,866
6103	143	.....do	3.40	21.23	9.14	52.29	17.34	5,035
6104	144	.....do	3.78	23.63	8.41	52.62	15.34	5,065
6124	145	.....do	3.01	18.81	12.47	43.71	25.01	5,844

EXPERIMENTS ON THE DIGESTIBILITY OF BREAD.

DIGESTION EXPERIMENTS WITH MEN.

The experiments here reported were made during the years 1896 and 1897. The subjects were young men students, with vigorous appetites and apparently normal digestion. Usually two or more experiments upon different subjects were carried on at the same time. The meals were taken in a dining room so arranged that the subjects could eat together under conditions as nearly normal as possible.

No attempt was made to limit the amount of food taken except in experiment No. 146, which was designed to show the results of partial fasting. The food of each man was kept separate. Whenever a new loaf of bread was needed it was weighed and quartered, one quarter serving as a sample for analysis. At the close of the experiment the uneaten food remaining was weighed and the amount deducted from the amount furnished. The difference was taken as the weight of the food eaten.

Each experiment was preceded by a supper of milk. Lampblack was taken in gelatin capsules with the milk, in order to facilitate the separation of the feces due to the food previous to the experiment from those of the experiment proper, which began in every case with breakfast the next morning. During the two following days the food consisted chiefly of the particular kind of bread under investigation. With the exception of the first four experiments, butter was eaten with the bread and the subjects were allowed milk and coffee, with sugar. The quantities and proportions of food were largely matters of individual selection. No attempt was made to have these the same in successive experiments. On the morning following the second day of the digestion experiment lampblack was administered in gelatin capsules with a breakfast of milk, and no solid food was taken until noon.

The separation of the feces due to the diet under investigation was easily made at the line of demarcation between the portion deeply colored by the lampblack and the lighter portion due to ordinary food. It was assumed that none of the feces from the given diet was colored by the lampblack. While it is not thought that this method of separation of the feces gives entirely satisfactory results, it seems to us at present the best available. Experiments are now being conducted which it is hoped may lead to a more satisfactory method.

In nearly all of the digestion experiments the urine was collected for the two days of bread diet, beginning with the time at which breakfast was taken. Of course it is not to be understood that the urine eliminated during this period represents the amount metabolized from the bread and other food eaten during this time. But since the urine can not be separated even as satisfactorily as the feces, and since there are no definite data at present regarding the duration of the so-called nitrogen lag, the urine was collected simply for the time covered by the digestion experiment. The amount of nitrogen in the urine for each experiment, and in several instances the heat of combustion of the dried matter, were determined.

The details of the digestion experiments are included in the following tables. These show the kind and amount of food eaten by the subject, and in some instances the weight of the subject at the beginning and end of the experiment. The quantities in the column "total organic matter" are the sums of the quantities in the three following columns—protein, fat, and carbohydrates. The amount of protein, fat, and carbohydrates in each food material and in the feces was computed from the weight of each material multiplied by its percentage composition as shown in Tables 1 and 3. The heats of combustion shown in the last column of the tables were determined by burning the material in the bomb calorimeter and multiplying the total weight of food or feces by the heat of combustion of 1 gram as thus determined. The differences between the total nutrients in the food eaten and those rejected in the feces are taken as a measure of the total amounts digested, or, better, the amounts available for the body. The feces do not consist entirely of undigested residues, but contain a relatively large amount of metabolic products, as is explained beyond (p. 33). The amounts of nutrients rejected in the feces, while not strictly representing the undigested portion of the food, do represent approximately the amounts which are not available to the body.[1] The total amount of any particular kind of nutrient digested or available divided by the total amount of this nutrient in the food gives the percentage which is digestible or actually available to the body. These percentage values are called coefficients of digestibility or availability.

While the coefficients of digestibility of the different nutrients represent the proportion which the body actually utilizes, the corresponding value for the heat of combustion of the food does not represent the actual amount of energy which the body obtains from the food absorbed from the alimentary canal. When protein is burned in the bomb calorimeter the carbon is oxidized to carbon dioxid and the hydrogen to water. The nitrogen is left in the free state. When protein is burned in the body, however, the oxidation is not so complete. The nitrogen is excreted in the form of urea, uric acid, and other allied compounds, which also contain small amounts of carbon and hydrogen, together with some oxygen. In estimating the actual fuel values of the digestible nutrients of the food, allowance must be made for these incompletely oxidized residual products which are excreted by the kidneys. Urea is the most abundant of these excretory products, and it has frequently been assumed that all of the nitrogen excreted in the urine is thus combined, and allowance is made for the heat of combustion of the amount of urea corresponding to the amount of nitrogen found in the urine. According to this last supposition 0.87 calories of the energy latent in each gram of digestible protein would be lost to the body in the urea formed from the nitrogen of the protein.[1] In a considerable number of actual determinations of the ratio of the nitrogen to heat of combustion in urine of healthy men made by Atwater and associates at Middletown, Conn., the average heat of combustion of the organic matter in the urine corresponding to 1 gram of digestible protein amounts to 1.25 calories. As a result of four determinations of the heat of combustion of the urine in the experiments here reported the factor 1.16 was obtained. Since Atwater's factor is based upon a considerably larger number of determinations, it is used in the following tables for the calculation of the energy of the digestible protein which is carried away in the unoxidized organic matter of the urine, and hence is not available to the body.

---

[1] See discussion of this subject in Connecticut Storrs Sta. Rpts. 1896, p. 166, and 1897, p. 156.

The figures given in Tables 4–27 for the proportion of energy actually available to the body in the food eaten are obtained, therefore, by deducting from the total energy of the digested food the energy lost to the body in organic matter of the urine. This latter value is determined by multiplying the total amount of digestible protein by 1.25.

In connection with the majority of the digestion experiments reported beyond, the outgo of nitrogen in the urine was determined, as explained above. Following the tabular details of each experiment is a paragraph showing the nitrogen balance in the particular instance—i. e., whether the subject gained or lost nitrogen during the two days of the test.

EXPERIMENTS WITH BREAD ALONE.

In the first four digestion experiments no food was eaten except bread. To render the diet more palatable the subjects were allowed beef tea and water ad libitum. The results of the experiments are shown in the following tables:

DIGESTION EXPERIMENT No. 123.

Kind of food.—White bread.

Subject.—H. B. S.

Weight (*without clothing*).—At beginning, 145 pounds; at end, 147 pounds.

Duration.—Two days, with six meals.

---

[1] Urea contains 46.67 per cent nitrogen and has a heat of combustion of 2.54 calories per gram. One gram of protein (16 per cent nitrogen) would yield (16÷46.67=) 0.342 gram urea with a heat of combustion of (2.54×0.342=)0.87. See also U. S. Dept. Agr., Office of Experiment Stations Bul. 53, pp. 27 and 28.

TABLE 4.—*Results of digestion experiment No. 123.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25.)	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6001	White bread	1,633	1,032.7	143.4	28.8	861.0	11.4	4,639
6020	Feces (water-free)	39.0	32.6	13.1	5.0	14.5	6.4	178
	Amount digested..	....	1,000.1	130.3	23.3	846.5	5.0	4,461
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food........	....	96.8	90.9	82.3	98.3	43.9	(96.2)
	Proportion of energy actually available to body	....	....	....	....	....	....	92.7

During this experiment the subject eliminated 2,142 grams of urine, containing 1.81 per cent or 38.8 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 11.5 grams; outgo in urine, 19.4 grams, and in feces, 1.1 grams; implying a loss of 9 grams nitrogen, corresponding to 56.3 grams protein.

DIGESTION EXPERIMENT No. 124.

Kind of food.—White bread.
Subject.—H. B. S.
Duration.—Two days, with six meals.

TABLE 5.—*Results of digestion experiment No. 124.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6002	White bread	956	619.3	83.0	16.0	520.3	7.0	2,809
6021	Feces (water-free)	31	27.8	16.6	5.5	5.7	3.2	165
	Amount digested..	....	591.5	66.4	10.5	514.6	3.8	2,644
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food........	....	95.5	80.0	65.6	98.9	54.3	94.1
	Proportion of energy actually available to body	....	....	....	....	....	....	91.2

During this experiment the subject eliminated 1,550 grams urine, containing 1.20 per cent or 18.6 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 6.7 grams; outgo in urine, 9.3 grams, and in feces, 1.4 grams; implying a loss of 4 grams nitrogen, corresponding to 25 grams protein.

DIGESTION EXPERIMENT No. 125.

Kind of food.—White bread.
Subject.—L. H. H.
Duration.—Two days, with six meals.

TABLE 6.—*Results of digestion experiment No. 125.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6003	White bread	1,080	691.3	93.8	20.6	576.9	14.1	3,160
6022	Feces (water-free)	47	37.5	17.5	6.7	13.3	9.5	213
	Amount digested		653.8	76.3	13.9	563.6	4.6	2,947
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		94.6	81.7	67.5	97.7	32.6	(93.3)
	Proportion of energy actually available to body							90.3

During this experiment the subject eliminated 1,545 grams urine, containing 1.30 per cent or 20.1 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 7.5 grams; outgo in urine, 10.1 grams, and in feces, 1.4 grams; implying a loss of 4 grams nitrogen, corresponding to 25 grams protein.

DIGESTION EXPERIMENT No. 126.

Kind of food.—White bread.
Subject.—L. W. F.
Duration.—Two days, with six meals.

TABLE 7.—*Results of digestion experiment No. 126.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6004	White bread	1,069	689.5	93.3	18.6	577.6	14.9	3,141
6023	Feces (water-free)	41.7	36.8	23.0	6.1	7.7	4.9	205
	Amount digested		652.7	70.3	12.5	569.9	10.0	2,936
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		94.7	75.4	67.2	98.7	67.1	93.5
	Proportion of energy actually available to body							90.7

During this experiment the subject eliminated 1,509 grams urine, containing 1.53 per cent or 23.1 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 7.5 grams; outgo in urine, 13.4 grams, and in feces, 1.8 grams; implying a loss of 5.9 grams nitrogen, corresponding to 36.9 grams protein.

EXPERIMENTS WITH MIXED DIET, LARGELY BREAD.

In the four digestion experiments Nos. 123–126 no other food besides bread was taken, but since it has been observed that the nutrients of a given article are more thoroughly assimilated when it is consumed with some other food than when eaten alone, in the other experiments, Nos. 127–146, milk, butter, and sugar were allowed. In the following tables, Nos. 8–27, the results of these experiments are shown, together with the computed digestibility of the bread alone. These tables differ from those preceding in that they show the estimated feces from food other than bread, the estimated digestible nutrients in the bread, and the computed coefficients of digestibility of bread alone.

Calculated digestibility of bread alone.—In order to calculate the digestibility of the bread alone from the results obtained in the mixed diet it is necessary to assume more or less arbitrary factors for the digestibility of the food materials eaten with the bread. From a study of the results of digestion experiments made in this country and Europe it was assumed that 98 per cent of the protein, 99 per cent of the fat and 99 per cent of the carbohydrates of the milk, and 99 per cent of the fat of the butter consumed with the bread would be actually available to the body. Sugar is usually regarded as wholly digested, but when taken in considerable quantities it seems hardly probable that it is absorbed from the alimentary canal without the expenditure of some digestive juices which would be eliminated to a greater or less extent as metabolic products in the feces. In calculating the results of the experiments it is assumed, therefore, that only 98 per cent of the carbohydrates of sugar is actually available to the body. The application of these factors to the results of other experiments, as well as to those here reported, seems to show that the proportions above indicated represent approximately the percentages of digestibility for the nutrients of these food materials.

An illustration of the method of calculation may make the matter clearer. In experiment No. 127 there was a total of 151.5 grams of protein consumed in the two days, of which 56.5 came from the milk. It is assumed that 98 per cent of this protein of milk was available to the body, leaving 1.1 grams in the feces. In the total feces in this digestion experiment there was 20.5 grams of protein (N×6.25), leaving 19.4 grams as coming from the undigested or unavailable portion of the bread. The total amount of protein digested was 131 grams. The total protein in the bread eaten was 95 grams, and the estimated digestible nutrients in bread was therefore (95.0—19.4=) 75.6 grams. In order to obtain the coefficient of digestibility of the protein of the total food we divide 131 by 151.5, obtaining 86.5 per cent as the result. The estimated coefficient of digestibility of the bread alone is obtained by dividing 75.6 by 95, giving 79.6 per cent. Similar computations serve for the calculation of the digestibility of the fat and carbohydrates of the bread alone. The proportion of energy actually available to the body in the total food is obtained, as explained above, by multiplying the digestible protein (131 grams) by 1.25 and deducting the total energy thus estimated as lost in the organic matter of the urine from the energy of the food digested. In a similar manner the digestible protein in the bread alone (75.6) multiplied by 1.25 gives the amount of energy of the bread which is eliminated in the organic matter of the urine. The percentage of total energy which is actually available to the body is then obtained by dividing the energy of the food digested (4,548 calories), less the energy lost in the urine (131×1.25=164 calories), by the energy in the total food (4,661 calories). The proportion of energy in the bread which is actually available is obtained in a like manner by dividing the difference between the estimated available energy in the bread (3,191) and the energy lost in the urine (75.6×1.25=95.0) by the total energy in the bread eaten (3,284 calories).

The details of the experiments are as follows:

DIGESTION EXPERIMENT No. 127.

Kind of food.—White bread with milk.
Subject.—L. H. H.
Duration.—Two days, with six meals.

TABLE 8.—*Results of digestion experiment No. 127.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6005	White bread	1,116.0	713.7	95.0	33.3	585.4	22.1	3,284
6008	Milk	803.3	99.3	24.6	29.7	45.0	6.2	636
6009	.....do	927.0	114.7	31.9	37.1	45.7	7.0	741
	Total	....	927.7	151.5	100.1	676.1	35.3	4,661
6024	Feces (water-free)	51.8	44.3	20.5	10.4	13.4	7.5	113
	Estimated feces from food other than bread	....	3.6	1.1	.7	1.8	....	20
	Estimated feces from bread	....	40.7	19.4	9.7	11.6	....	93
	Total amount digested	....	883.4	131.0	89.7	662.7	27.8	4,548
	Estimated digestible nutrients in bread	....	673.0	75.6	23.6	573.8	....	3,191
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	95.2	86.5	89.6	98.0	78.8	(97.6)
	Estimated coefficients of digestibility of bread alone	....	94.3	79.6	70.8	98.0	....	(97.0)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	94.1
	In bread alone	....	....	....	....	....	....	94.3

During this experiment the subject eliminated 1,443 grams, containing 1.84 per cent or 26.6 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 12.1 grams; outgo in urine, 13.3 grams, and in feces, 1.7 grams; making a loss of 2.9 grams nitrogen, corresponding to 18.1 grams protein.

DIGESTION EXPERIMENT No. 128.

Kind of food.—White bread with milk.
Subject.—H. B. S.
Duration.—Two days, with six meals.

TABLE 9.—*Results of digestion experiment No. 128.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6006	White bread	977.0	632.3	83.9	21.8	526.6	18.9	2,892
6008	Milk	1,390.5	171.8	42.5	51.4	77.9	10.7	1,101
6009	....do	1,339.0	165.7	46.1	53.6	66.0	10.2	1,070
	Total	....	969.8	172.5	126.8	670.5	39.8	5,063
6025	Feces (water-free)	52.6	40.7	15.9	9.1	15.7	11.9	236
	Estimated feces from food other than bread	....	5.8	1.8	1.1	2.9	....	31
	Estimated feces from bread	....	34.9	14.1	8.0	12.8	....	205
	Total amount digested	....	929.1	156.6	117.7	654.8	27.9	4,827
	Estimated digestible nutrients in bread	....	597.4	69.8	13.8	513.8	....	2,687
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	95.8	90.8	92.8	97.7	70.1	(95.3)
	Estimated coefficients of digestibility of bread alone	....	94.5	83.2	63.1	97.6	....	(92.9)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	91.5
	In bread alone	....	....	....	....	....	....	89.9

During this experiment the subject eliminated 2,279 grams of urine, containing 1.23 per cent or 28 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 13.8 grams; outgo in urine, 14 grams, and in feces, 1.3 grams; making a loss of 1.5 grams nitrogen, corresponding to 9.4 grams protein.

DIGESTION EXPERIMENT No. 129.

Kind of food.—White bread with milk.
Subject.—C. W. S.
Duration.—Two days, with six meals.

TABLE 10.—*Results of digestion experiment No. 129.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6007	White bread	2,042	1,240.4	193.9	16.5	1,030.0	15.5	5,509
6010	Milk	1,548	190.8	51.2	61.9	77.7	12.4	1,197
6011	.....do	2,064	262.5	68.3	87.7	106.5	15.7	1,666
	Total	....	1,693.7	313.4	166.1	1,214.2	43.6	8,372
	Feces (water-free)	76.9	60.2	25.3	9.6	25.3	16.7	342
	Estimated feces from food other than bread	....	7.6	2.4	1.5	3.7	....	42
	Estimated feces from bread	....	52.6	22.9	8.1	21.6	....	300
	Total amount digested	....	1,633.5	288.1	156.5	1,188.9	26.9	8,030
	Estimated digestible nutrients in bread	....	1,187.8	171.0	8.4	1,008.4	....	5,209
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	96.5	91.9	94.2	97.9	61.7	(95.9)
	Estimated coefficients of digestibility of bread alone	....	95.8	88.2	50.9	97.9	....	(94.6)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	91.6
	In bread alone	....	....	....	....	....	....	90.7

During this experiment the subject eliminated 2,505 grams urine, containing 1.68 per cent or 42.1 grams nitrogen. This makes the average nitrogen per day as follows: Income in food, 25.1 grams; outgo in urine, 21.1 grams, and in feces, 2 grams; making a gain of 2 grams nitrogen, corresponding to 12.5 grams protein.

DIGESTION EXPERIMENT No. 130.

Kind of food.—White bread with milk.
Subject.—P. F. F.
Duration.—Two days, with six meals.

TABLE 11.—*Results of digestion experiment No. 130.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6007	White bread	1,197.0	726.9	113.7	9.7	603.5	9.1	3,230
6010	Milk	1,826.6	225.3	60.5	73.1	91.7	14.6	1,428
6011	.....do	1,702.8	216.6	56.4	72.4	87.8	12.9	1,374
	Total	....	1,168.8	230.6	155.2	783.0	36.6	6,032
6027	Feces (water-free)	76.1	60.1	25.0	18.0	17.1	16.0	375
	Estimated feces from food other than bread	....	7.4	2.3	1.5	3.6	....	41
	Estimated feces from bread	....	52.7	22.7	16.5	13.5	....	334
	Total amount digested	....	1,108.7	205.6	137.2	765.9	20.6	5,657
	Estimated digestible nutrients in bread	....	....	91.0	....	590.0	....	2,896
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	94.9	89.2	88.4	97.8	56.1	(93.8)
	Estimated coefficients of digestibility of bread alone	....	....	80.1	....	97.8	....	(89.7)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	89.5
	In bread alone	....	....	....	....	....	....	86.1

During this experiment the subject eliminated 2,550 grams urine, containing 1.39 per cent or 35.4 grams nitrogen. This makes the average nitrogen balance as follows: Income in food, 18.5 grams; outgo in urine, 17.7 grams, and in feces, 2 grams; making a loss of 1.2 grams nitrogen, corresponding to 7.5 grams protein.

DIGESTION EXPERIMENT No. 131.

Kind of food.—Graham bread with milk.
Subject.—C. W. S.
Duration.—Two days, with six meals.

TABLE 12.—*Results of digestion experiment No. 131.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6034	Graham bread	1,593.0	1,096.3	161.0	20.5	914.8	48.0	4,830
6032	Milk	2,218.8	284.5	76.3	88.8	119.4	16.2	1,826
6033	do	2,579.0	340.1	85.4	101.8	152.9	19.1	2,112
	Total	....	1,720.9	322.7	211.1	1,187.1	83.3	8,768
6042	Feces (water-free)	153.3	126.6	39.4	11.9	75.3	26.7	637
	Estimated feces from food other than bread	....	10.6	3.2	1.9	5.5	....	58
	Estimated feces from bread	....	116.0	36.2	10.0	69.8	....	579
	Total amount digested	....	1,594.3	283.3	199.2	1,111.8	56.6	8,131
	Estimated digestible nutrients in bread	....	980.3	124.8	10.5	845.0	....	4,251
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	92.6	87.8	94.4	93.7	68.0	(92.7)
	Estimated coefficients of digestibility of bread alone	....	89.4	77.5	51.3	92.4	....	(86.0)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	88.6
	In bread alone	....	....	....	....	....	....	84.8

During this experiment the subject eliminated 1,408 grams urine, containing 1.22 per cent or 17.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 25.8 grams; outgo in urine, 8.6 grams, and in feces, 3.2 grams; making a gain of 14 grams nitrogen, corresponding to 87.5 grams nitrogen.

DIGESTION EXPERIMENT No. 132.

Kind of food.—Graham bread with milk.
Subject.—F. H. M.
Duration.—Two days, with six meals.

TABLE 13.—*Results of digestion experiment No. 132.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6035	Graham bread	1,317.0	739.3	108.5	18.8	617.0	25.6	3,262
6032	Milk	1,341.6	172.0	46.1	53.7	72.2	9.8	1,104
6033	....do	2,717.0	358.3	89.9	107.3	161.1	20.1	2,225
	Total	....	1,269.6	244.5	174.8	850.3	55.5	6,591
6043	Feces (water-free)	104.6	84.7	27.7	10.4	46.6	19.9	440
	Estimated feces from food other than bread	....	9.0	2.7	1.6	4.7	....	49
	Estimated feces from bread	....	75.7	25.0	8.8	41.9	....	391
	Total amount digested	....	1,184.9	216.8	164.4	803.7	35.6	6,151
	Estimated digestible nutrients in bread	....	663.6	83.5	5.0	575.1	....	2,871
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	93.3	88.7	94.1	94.5	64.1	(93.3)
	Estimated coefficients of digestibility of bread alone	....	89.8	77.0	36.3	93.2	....	(93.7)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	89.2
	In bread alone	....	....	....	....	....	....	84.8

During this experiment the subject eliminated 3,488 grams urine, containing 1.29 per cent or 45 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 19.6 grams; outgo in urine, 22.5 grams, and in feces, 2.2 grams; making a loss of 5.1 grams nitrogen, corresponding to 31.9 grams protein.

DIGESTION EXPERIMENT No. 133.

Kind of food.—Graham bread with milk.
Subject.—C. D. H.
Duration.—Two days, with six meals.

TABLE 14.—*Results of digestion experiment No. 133.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6030	Graham bread	1,361.0	629.7	92.0	12.3	525.4	26.2	2,788
6032	Milk	2,734.0	350.5	94.0	109.4	147.1	20.0	2,250
6033	....do	2,889.6	381.1	95.6	114.1	171.4	21.4	2,367
	Total	....	1,361.3	281.6	235.8	843.9	67.6	7,405
6044	Feces (water-free)	97.5	77.6	22.8	7.8	47.0	19.9	391
	Estimated feces from food other than bread	....	12.4	3.8	2.2	6.4	....	68
	Estimated feces from bread	....	65.2	19.0	5.6	40.6	....	323
	Total amount digested	....	1,283.7	258.8	228.0	796.9	47.7	7,014
	Estimated digestible nutrients in bread	....	564.5	73.0	6.7	484.8	....	2,465
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	94.3	91.9	96.7	94.4	70.6	(34.7)
	Estimated coefficients of digestibility of bread alone	....	89.6	79.3	54.7	92.3	....	(88.4)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	90.4
	In bread alone	....	....	....	....	....	....	85.2

During this experiment the subject eliminated 2,433 grams urine, containing 0.87 per cent or 21.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 22.6 grams; outgo in urine, 10.6 grams, and in feces, 1.8 grams; making a gain of 10.2 grams nitrogen, corresponding to 63.8 grams protein.

DIGESTION EXPERIMENT No. 134.

Kind of food.—Graham bread with milk.
Subject.—P. F. F.
Duration.—Two days, with six meals.

TABLE 15.—*Results of digestion experiment No. 134.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6037	Graham bread	1,326.0	736.9	104.2	15.4	617.3	27.1	3,257
6032	Milk	2,165.2	277.6	74.5	86.6	116.5	15.8	1,782
6033	do	2,683.0	353.8	88.8	106.9	159.1	19.9	2,199
	Total		1,368.3	267.5	207.9	892.9	62.8	7,238
6045	Feces (water-free)	134.5	105.6	34.2	11.5	59.9	28.9	541
	Estimated feces from food other than bread		10.7	3.3	1.9	5.5		59
	Estimated feces from bread		94.9	30.9	9.6	54.4		482
	Total amount digested		1,262.7	233.3	196.4	833.0	33.9	6,697
	Estimated digestible nutrients in bread		642.0	73.3	5.8	562.9		2,775
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		92.3	87.2	94.5	93.3	54.0	(92.5)
	Estimated coefficients of digestibility of bread alone		87.1	70.3	87.9	91.2		(85.2)
	Proportion of energy actually available to body:							
	In total food							88.5
	In bread alone							82.4

During this experiment the subject eliminated 2,745 grams urine, containing 1 per cent or 27.5 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 21.4 grams; outgo in urine, 13.8 grams, and in feces, 2.7 grams; making a gain of 4.9 grams nitrogen, corresponding to 30.6 grams protein.

DIGESTION EXPERIMENT No. 135.

Kind of food.—Entire wheat bread with milk.
Subject.—C. W. S.
Duration.—Two days, with six meals.

TABLE 16.—*Results of digestion experiment No. 135.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6047	Entire wheat bread	1,579.0	883.3	133.4	6.7	743.2	29.1	3,895
6046	Milk	2,064.0	266.0	71.0	85.6	109.4	14.9	1,692
6057	do	2,274.0	290.6	78.2	91.0	121.4	18.0	1,847
	Total		1,439.9	282.6	183.3	974.0	62.0	7,434
	Feces (water-free)	96.6	77.4	30.8	12.4	34.2	19.2	424
	Estimated feces from food other than bread		9.4	3.0	1.8	4.6		52
	Estimated feces from bread		68.0	27.8	10.6	29.6		372
	Total amount digested		1,362.5	251.8	170.9	939.8	42.8	7,010
	Estimated digestible nutrients in bread			105.6		713.6		3,523
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		94.6	89.1	93.2	96.5	69.0	(94.3)
	Estimated coefficients of digestibility of bread alone			79.2		96.0		(90.4)
	Proportion of energy actually available to body:							
	In total food							90.1
	In bread alone							87.1

During this experiment the subject eliminated 2,334 grams urine, containing 1.33 per cent or 31 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 22.6 grams; outgo in urine, 15.5 grams, and in feces, 2.5 grams; making a gain of 4.6 grams nitrogen, corresponding to 28.8 grams protein.

DIGESTION EXPERIMENT No. 136.

Kind of food.—Entire wheat bread with milk.
Subject.—P. F. F.
Duration.—Two days, with six meals.

TABLE 17.—*Results of digestion experiment No. 136.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6048	Entire wheat bread	1,949.0	1,130.0	171.0	8.2	950.8	37.3	4,989
6046	Milk	2,992.8	385.8	103.0	124.2	158.6	21.6	2,454
6057	do	2,585.0	330.3	88.9	103.4	138.0	20.4	2,100
	Total		1,846.1	362.9	235.8	1,247.4	79.3	9,543
6052	Feces (water-free)	75.8	55.8	23.3	6.5	26.0	20.0	295
	Estimated feces from food other than bread		12.0	3.8	2.3	5.9		67
	Estimated feces from bread		43.8	19.5	4.2	20.1		228
	Total amount digested		1,790.3	339.6	229.3	1,221.4	59.3	9,248
	Estimated digestible nutrients in bread		1,086.2	151.5	4.0	930.7		4,761
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		97.0	93.6	97.2	97.9	74.8	96.9
	Estimated coefficients of digestibility of bread alone		96.1	88.6	48.4	97.9		95.5
	Proportion of energy actually available to body:							
	In total food							92.5
	In bread alone							91.6

During this experiment the subject eliminated 2,046 grams urine, containing 1.38 per cent or 28.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 29.1 grams; outgo in urine, 14.1 grams, and in feces, 1.9 grams; making a gain of 13.1 grams nitrogen, corresponding to 81.9 grams protein.

DIGESTION EXPERIMENT No. 137.

Kind of food.—Entire wheat bread with milk.

Subject.—A. B. O.

Duration.—Two days, with six meals.

TABLE 18.—*Results of digestion experiment No. 137.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6049	Entire wheat bread	1,600.0	923.8	139.0	6.9	777.9	30.2	4,093
6046	Milk	2,373.6	305.9	81.6	98.5	125.8	17.1	1,946
6057	do	2,585.0	330.3	88.9	103.4	138.0	20.4	2,100
	Total	....	1,560.0	309.5	208.8	1,041.7	67.7	8,139
6053	Feces (water-free)	78.6	60.0	22.5	8.1	29.4	18.6	320
	Estimated feces from food other than bread	....	10.7	3.4	2.0	5.3	....	59
	Estimated feces from bread	....	49.3	19.1	6.1	24.1	....	261
	Total amount digested	....	1,500.0	287.0	200.7	1,012.3	49.1	7,819
	Estimated digestible nutrients in bread	....	874.5	119.9	.8	753.8	....	3,832
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	96.2	92.7	96.1	97.2	72.5	(96.1)
	Estimated coefficients of digestibility of bread alone	....	94.7	86.3	10.4	96.9	....	(93.6)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	91.7
	In bread alone	....	....	....	....	....	....	90.0

During this experiment the subject eliminated 3,450 grams urine, containing 1.14 per cent or 39.3 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 24.8 grams; outgo in urine, 19.7 grams, and in feces, 1.8 grams; making a gain of 3.3 grams nitrogen, corresponding to 20.6 grams protein.

DIGESTION EXPERIMENT No. 138.

Kind of food.—White bread with milk.

Subject.—A. J. P.

Weight (*without clothing*).—At beginning, 136.9 pounds; at end, 136.3 pounds.

Duration.—Two days, with six meals.

TABLE 19.—*Results of digestion experiment No. 138.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6064	White bread	1,328.6	806.1	120.5	25.9	659.7	17.1	4,744
6066	Milk	800.0	96.9	28.0	33.6	35.3	5.5	582
6068	.....do	1,800.0	224.8	66.4	75.6	82.8	12.6	1,438
6071	.....do	1,200.0	151.0	42.0	50.4	58.6	8.4	902
6067	Butter	185.0	159.7	2.4	157.3	....	7.0	1,476
	Sugar	53.0	53.0	....	....	53.0	....	211
	Total	....	1,491.5	259.3	342.8	889.4	50.6	9,353
	Feces (water-free)	34.1	26.0	9.4	5.8	10.8	8.1	196
	Estimated feces from food other than bread	....	10.6	2.8	3.2	4.6	....	63
	Estimated feces from bread	....	15.4	6.6	2.6	6.2	....	133
	Total amount digested	....	1,465.5	249.9	337.0	878.6	42.5	9,157
	Estimated digestible nutrients in bread	....	790.7	113.9	23.3	653.5	....	4.611
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	98.3	96.3	98.3	98.8	84.0	(97.9)
	Estimated coefficients of digestibility of bread alone	....	98.1	94.5	89.9	99.1	....	(97.2)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	94.6
	In bread alone	....	....	....	....	....	....	94.2

During this experiment the subject eliminated 2,749 grams urine, containing 1.42 per cent or 39 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 20.8 grams; outgo in urine, 19.5 grams, and in feces, 0.8 gram; making a gain of 0.5 gram nitrogen, corresponding to 3.1 grams protein.

DIGESTION EXPERIMENT No. 139.

Kind of food.—White bread with milk, butter, and sugar.

Subject.—B. R. M.

Weight (*without clothing*).—At beginning, 165.4 pounds; at end, 164.2 pounds.

Duration.—Two days, with six meals.

TABLE 20.—*Results of digestion experiment No. 139.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6065	White bread	1,642.2	1,006.4	150.9	30.7	824.8	21.2	4,664
6066	Milk	800.0	96.9	28.0	33.6	35.3	5.5	582
6068	.....do	1,455.0	181.7	53.7	61.1	66.9	10.2	1,163
6071	.....do	800.0	100.6	28.0	33.6	39.0	5.6	602
6067	Butter	259.6	224.0	3.4	220.6	....	9.8	2,070
	Sugar	148.6	148.6	....	....	148.6	....	592
	Total	....	1,758.2	264.0	379.6	1,114.6	52.3	9,673

TABLE 20.—*Results of digestion experiment No. 139*—Continued.

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6070	Feces (water-free)	74.3	61.9	22.6	20.4	18.9	12.4	447
	Estimated feces from food other than bread		12.6	3.3	3.5	5.8		68
	Estimated feces from bread		49.3	19.3	16.9	13.1		379
	Total amount digested		1,696.3	241.4	359.2	1,095.7	39.9	9,226
	Estimated digestible nutrients in bread		957.1	131.6	13.8	811.7		4,285
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		96.5	91.4	94.6	98.3	76.3	(95.4)
	Estimated coefficients of digestibility of bread alone		95.1	87.2	45.0	98.4		(91.9)
	Proportion of energy actually available to body:							
	In total food							92.3
	In bread alone							88.3

During this experiment the subject eliminated 2,208 grams urine, containing 1.69 per cent or 37.3 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 21.1 grams; outgo in urine, 18.7 grams, and in feces, 1.8 grams; making a gain of 0.6 gram nitrogen, corresponding to 3.8 grams protein.

DIGESTION EXPERIMENT No. 140.

Kind of food.—White bread with milk, butter, and sugar.

Subject.—A. J. P.

Weight (*without clothing*).—At beginning, 134.5 pounds; at end, 134.5 pounds.

Duration.—Two days with six meals.

TABLE 21.—*Results of digestion experiment No. 140.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6077	White bread	1,168.6	716.3	104.9	27.9	583.5	15.8	3,325
6079	Milk	2,200.0	288.7	72.8	93.5	122.4	11.0	1,753
6080	do	1,600.0	202.0	57.0	63.7	81.3	8.6	1,238
6081	Butter	146.4	122.7	2.0	120.7		6.9	1,133
	Sugar	59.6	59.6			59.6		238
	Total		1,389.3	236.7	305.8	846.8	42.3	7,687
6082	Feces (water-free)	44.0	32.5	10.9	5.7	15.9	11.5	247
	Estimated feces from food other than bread		10.8	2.7	2.8	5.3		62
	Estimated feces from bread		21.7	8.2	2.9	10.6		185
	Total amount digested		1,356.8	225.8	300.1	830.9	30.8	7,440
	Estimated digestible nutrients in bread		694.6	96.7	25.0	572.9		3,140
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		97.7	95.4	98.1	98.1	72.8	(96.8)
	Estimated coefficients of digestibility of bread alone		97.0	92.2	89.6	98.2		(93.2)
	Proportion of energy actually available to body:							
	In total food							93.1
	In bread alone							90.8

During this experiment the subject eliminated 2,322 grams urine, containing 1.54 per cent or 35.8 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 19 grams; outgo in urine, 17.9 grams, and in feces, 0.9 gram; making a gain of 0.2 gram nitrogen, corresponding to 1.3 grams protein.

DIGESTION EXPERIMENT No. 141.

Kind of food.—White bread with milk, butter, and sugar

Subject.—O. W. K.

Weight.—At beginning, 135.1 pounds; at end, 134 pounds.

Duration.—Two days with six meals.

TABLE 22.—*Results of digestion experiment No. 141.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6078	White bread	1,137.6	692.7	102.0	26.0	564.7	17.0	3,218
6079	Milk	2,200.0	288.7	72.8	93.5	122.4	11.0	1,753
6080	.....do	1,600.0	202.0	57.0	63.7	81.3	8.6	1,238
6081	Butter	135.6	113.7	1.9	111.8	....	6.4	1,040
	Sugar	80.4	80.4	....	....	80.4	....	321
	Total	....	1,377.5	233.7	295.0	848.8	43.0	7,570
6083	Feces (water-free)	42.0	32.4	10.8	5.0	16.6	9.6	242
	Estimated feces from food other than bread	....	11.1	2.7	2.7	5.7	....	64
	Estimated feces from bread	....	21.3	8.1	2.3	10.9	....	178
	Total amount digested	....	1,345.1	222.9	290.0	832.2	33.4	7,328
	Estimated digestible nutrients in bread	....	671.4	93.9	23.7	553.8	....	3,040
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total bread	....	97.7	95.4	98.3	98.1	80.0	(96.8)
	Estimated coefficients of digestibility of bread alone	....	96.9	92.1	91.2	98.1	....	(97.9)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	93.1
	In bread alone	....	....	....	....	....	....	90.8

During this experiment the subject eliminated 2,530 grams urine, containing 1.25 per cent or 31.6 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 18.7 grams; outgo in urine, 15.8 grams, and in feces, 0.9 gram; making a gain of 2 grams nitrogen, corresponding to 12.5 grams protein.

DIGESTION EXPERIMENT No. 142.

Kind of food.—Entire wheat bread with milk, butter, and sugar.

Subject.—A. J. P.

Weight (*without clothing*).—At beginning 132.5 pounds; at end 134.7 pounds.

Duration.—Two days with six meals.

TABLE 23.—*Results of digestion experiment No. 142.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6086	Entire wheat bread	1,247.6	751.7	117.6	32.7	601.4	17.5	3,567
6088	Milk	1,500.0	207.6	55.4	75.0	77.2	9.8	1,353
6089	do	545.0	73.0	19.4	27.2	26.4	3.1	467
6090	Butter	248.8	201.5	2.0	199.5	....	14.8	1,866
	Sugar	109.6	109.6	....	....	109.6	....	437
	Total	....	1,343.4	194.4	334.4	814.6	45.2	7,690
6091	Feces (water-free)	53.1	43.3	14.7	8.2	20.4	9.8	301
	Estimated feces from food other than bread	....	8.8	1.5	3.0	4.3	....	52
	Estimated feces from bread	....	34.5	13.2	5.2	16.1	....	249
	Total amount digested	....	1,300.1	179.7	326.2	794.2	35.4	7,389
	Estimated digestible nutrients in bread	....	717.2	104.4	27.5	585.3	....	3,318
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	96.8	90.4	97.5	97.5	78.3	(96.1)
	Estimated coefficients of digestibility of bread alone	....	95.4	88.8	84.0	97.3	....	(96.9)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	93.2
	In bread alone	....	....	....	....	....	....	89.3

During this experiment the subject eliminated 2,042 grams urine, containing 1.40 per cent or 28.6 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 15.6 grams; outgo in urine, 14.3 grams, and in feces, 1.5 grams; making a gain of 0.1 gram nitrogen, corresponding to 0.6 gram protein.

DIGESTION EXPERIMENT No. 143.

Kind of food.—Entire wheat bread with milk, butter, and sugar.

Subject.—O. W. K.

Weight (*without clothing*).—At beginning, 135.5 pounds; at end, 135.1 pounds.

Duration.—Two days, with six meals.

TABLE 24.—*Results of digestion experiment No. 143.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6087	Entire wheat bread	1,210.4	723.9	112.5	32.5	578.9	16.6	3,424
6088	Milk	1,500.0	207.6	55.4	75.0	77.2	9.8	1,353
6089	do	545.0	73.0	19.4	27.2	26.4	3.1	467
6090	Butter	267.6	216.8	2.2	214.6	....	15.9	2,008
	Sugar	184.8	184.8	....	....	184.8	....	737
	Total	....	1,406.1	189.5	349.3	867.3	45.4	7,989

TABLE 24.—*Results of digestion experiment No. 143*—Continued.

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6092	Feces (water-free)	44.8	36.6	12.4	7.0	17.2	8.2	275
	Estimated feces from food other than bread		10.5	1.5	3.2	5.8		61
	Estimated feces from bread		26.1	10.9	3.8	11.4		214
	Total amount digested		1,369.5	177.1	342.3	850.1	37.2	7,714
	Estimated digestible nutrients in bread		697.8	101.6	28.7	567.5		3,210
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		97.4	93.5	98.0	98.0	81.9	(96.8)
	Estimated coefficients of digestibility of bread alone		96.4	90.4	88.2	98.0		(93.8)
	Proportion of energy actually available to body:							
	In total food							93.7
	In bread alone							90.0

During this experiment the subject eliminated 2,086 grams urine, containing 1.46 per cent or 30.5 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 15.2 grams; outgo in urine, 15.3, and in feces, 1 gram; making a loss of 1.1 grams nitrogen, corresponding to 6.9 grams protein.

DIGESTION EXPERIMENT No. 144.

Kind of food.—Graham bread with milk, butter, and sugar.

Subject.—A. J. P.

Weight (*without clothing*).—At beginning, 136.1 pounds; at end, 135.7 pounds.

Duration.—Two days, with six meals.

TABLE 25.—*Results of digestion experiment No. 144.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6097	Graham bread	1,584.1	892.4	113.3	47.1	732.0	25.0	4,180
6099	Milk	1,200.0	158.2	43.6	55.2	59.4	9.0	1,065
6100	do	1,000.0	125.0	33.8	46.0	45.2	6.2	814
6107	Butter	189.8	152.4	2.1	150.3		12.3	1,410
	Sugar	102.0	102.0			102.0		407
	Total		1,430.0	192.8	298.6	938.6	52.5	7,876
6103	Feces (water-free)	284.5	91.5	23.5	10.1	57.9	19.3	558
	Estimated feces from food other than bread		8.2	1.6	2.5	4.1		49
	Estimated feces from bread		83.3	21.9	7.6	53.8		509
	Total amount digested		1,338.5	169.3	288.5	880.7	33.2	7,318
	Estimated digestible nutrients in bread		809.1	91.4	39.5	678.2		3,671
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		93.6	87.8	96.6	93.8	63.2	(92.9)
	Estimated coefficients of digestibility of bread alone		90.7	80.7	83.9	92.7		(87.8)
	Proportion of energy actually available to body:							
	In total food							90.2
	In bread alone							85.1

During this experiment the subject eliminated 2,723 grams urine, containing 1.10 per cent or 30 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 15.4 grams; outgo in urine, 15 grams, and in feces, 1.9 grams; making a loss of 1.5 grams nitrogen, corresponding to 9.4 grams protein.

DIGESTION EXPERIMENT No. 145.

Kind of food.—Graham bread with milk, butter, and sugar.

Subject.—O. W. K.

Weight (*without clothing*).—At beginning, 136.2 pounds; at end, 136 pounds.

Duration.—Two days, with six meals.

TABLE 26.—*Results of digestion experiment No. 145.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6098	Graham bread	1,200.0	679.8	89.1	33.0	557.7	17.6	3,178
6099	Milk	1,400.0	184.5	50.8	64.4	69.3	10.5	1,243
6100	....do	1,076.0	134.5	36.4	49.5	48.6	6.7	876
6107	Butter	201.4	161.7	2.3	159.4	....	13.0	1,495
	Sugar	185.0	185.0	....	....	185.0	....	738
	Total	....	1,345.5	178.6	306.3	860.6	47.8	7,530
6104	Feces (water-free)	93.1	78.8	22.0	7.8	49.0	14.3	472
	Estimated feces from food other than bread	....	10.6	1.8	2.7	6.1	....	60
	Estimated feces from bread	....	68.2	20.2	5.1	42.9	....	412
	Total amount digested	....	1,266.7	156.6	298.5	811.6	33.5	7,058
	Estimated digestible nutrients in bread	....	611.6	68.9	27.9	514.8	....	2,766
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food	....	94.1	87.7	97.5	94.3	70.1	(93.7)
	Estimated coefficients of digestibility of bread alone	....	90.0	77.3	84.6	92.3	....	(87.0)
	Proportion of energy actually available to body:							
	In total food	....	....	....	....	....	....	91.1
	In bread alone	....	....	....	....	....	....	84.3

During this experiment the subject eliminated 2,259 grams urine, containing 1.22 per cent or 27.6 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 14.3 grams; outgo in urine, 13.8 grams, and in feces, 1.8 grams; making a loss of 1.3 grams nitrogen, corresponding to 8.1 grams protein.

DIGESTION EXPERIMENT No. 146.

Kind of food.—White bread with milk, butter, and sugar. (Partial fasting.)

Subject.—O. W. K.

Weight (*without clothing*).—At beginning, 147.6 pounds; at end, 144.7 pounds.

Duration.—Two days, with six meals.

TABLE 27.—*Results of digestion experiment No. 146.*

Laboratory number.		Weight of material.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
6120	White bread	568.0	344.8	51.3	7.6	285.9	6.5	1,595
6121	Milk	1,629.6	223.3	59.2	88.0	76.1	12.2	1,463
	Butter	67.8	56.0	.8	55.2		2.8	516
	Sugar	40.2	40.2			40.2		125
	Total		664.3	111.3	150.8	402.2	21.5	3,699
6124	Feces (water-free)	12.4	9.3	2.4	1.5	5.4	3.1	50
	Estimated feces from food other than bread		4.9	1.2	1.4	2.3		29
	Estimated feces from bread		4.4	1.2	.1	3.1		21
	Total amount digested		655.0	108.9	149.3	396.8	18.4	3,649
	Estimated digestible nutrients in bread		340.4	50.1	7.5	282.8		1,574
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Coefficients of digestibility of total food		98.6	97.8	99.0	98.7	85.6	(98.6)
	Estimated coefficients of digestibility of bread alone		98.7	97.7	99.1	98.9		(98.7)
	Proportion of energy actually available to body:							
	In total food							95.0
	In bread alone							94.7

The quantity of food was limited in this experiment in order to obtain data for studying the amount of metabolic nitrogen in the feces, as explained on p. 39.

During this experiment the subject eliminated 1,529 grams urine, containing 1.58 per cent or 24.2 grams nitrogen. This makes the average nitrogen balance per day as follows: Income in food, 8.9 grams; outgo in urine, 12.1 grams, and in feces, 0.2 gram; making a loss of 3.4 grams nitrogen, corresponding to 21.3 grams protein.

In Table 28 are summarized the results obtained in the various digestion experiments for the digestibility of the total diet. In Table 29 these results are shown as computed for the digestibility of the different kinds of bread alone. It will be noticed that the digestibility of the bread in the first four experiments, in which no other food materials were consumed, was less than in the experiments in which milk was taken in addition.

TABLE 28.—*Summary of digestion experiments—Digestibility of nutrients and energy of total food.*

Number of experiment.	Kinds of food.	Subject.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*
123	White bread	H. B. S.	96.8	90.9	82.3	98.3	43.9	92.7
124	do	H. B. S.	95.5	80.0	65.6	98.9	54.3	91.2
125	do	L. H. H.	94.6	81.7	67.5	97.7	32.6	90.3
126	do	I. W. F.	94.7	75.4	67.2	98.7	67.1	90.7
	White bread, average of 4.		95.4	82.0	70.7	98.4	49.5	91.2
127	White bread and milk	L. H. H.	95.2	86.5	89.6	98.0	78.8	94.1
128	do	H. B. S.	95.8	90.8	92.8	97.7	70.1	91.5
129	do	C. W. S.	96.5	91.9	94.2	97.9	61.7	91.6
130	do	P. F. F.	94.9	89.2	88.4	97.8	56.1	89.5
138	do	A. J. P.	98.3	96.3	98.3	98.8	84.0	94.6
139	do	B. R. M.	97.8	91.4	94.6	98.3	76.3	92.3
140	do	A. J. P.	97.7	95.4	98.1	98.1	72.8	93.1
141	do	O. W. K.	97.7	95.4	98.3	98.1	80.0	93.1
146	do	O. W. K.	98.6	97.8	99.0	98.7	85.6	95.0
	Average of Nos. 129, 130, 138, 140, 141. *a*		97.0	93.6	95.5	98.1	70.9	92.4
	Average of 9		96.9	92.8	94.8	98.2	73.9	92.8
131	Graham bread and milk	C. W. S.	92.6	87.8	94.4	93.7	68.0	88.6
132	do	F. H. M.	93.3	88.7	94.1	94.5	64.1	89.2
133	do	C. D. H.	94.3	91.9	96.7	94.4	70.6	90.4
134	do	P. F. F.	92.3	87.2	94.5	93.3	54.0	88.5
144	do	A. J. P.	93.6	87.8	96.6	93.8	63.2	90.2
145	do	O. W. K.	94.1	87.7	97.5	94.3	70.1	91.1
	Average of Nos. 131, 134, 144, 145 *a*.		93.1	88.6	95.8	93.8	63.8	89.6
	Average of 6		93.4	88.5	95.6	94.0	65.0	89.7
135	Entire wheat bread and milk	C. W. S.	94.6	89.1	93.2	96.5	69.0	90.1
136	do	P. F. F.	97.0	93.6	97.2	97.9	74.8	92.5
137	do	A. B. O.	96.2	92.7	96.1	97.2	72.5	91.7
142	do	A. J. P.	96.8	90.4	97.5	97.5	78.3	93.2
143	do	O. W. K.	97.4	93.5	98.0	98.0	81.9	93.7
	Average of Nos. 135, 136, 142, 143 *a*.		96.5	91.7	96.5	97.5	76.0	92.4
	Average of 5		96.4	91.9	96.4	97.4	75.3	92.2

a These averages are more strictly comparable than the average of all, as they include experiments upon the same subjects with all three kinds of flours.

Table 29 summarizes the calculated digestibility of the bread alone in the preceding experiments.

TABLE 29.—*Digestibility of nutrients and energy of bread alone.*

Number of experiment.	Kinds of food.	Subject.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Heat of combustion.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per cent.*
123	White bread	H. B. S.	96.8	90.9	82.3	98.3	92.7
124	do	H. B. S.	95.5	80.0	65.6	98.9	91.2
125	do	L. H. H.	94.6	81.7	67.5	97.7	90.3
126	do	L. W. F.	94.7	75.4	67.2	98.7	90.7
127	do	L. H. H.	94.3	79.6	70.8	98.0	94.3
128	do	H. B. S.	94.5	83.2	63.1	97.6	89.9
129	do	C. W. S.	95.8	88.2	50.9	97.9	90.7
130	do	P. F. F.		80.1		97.8	86.1
138	do	A. J. P.	98.1	94.5	89.9	99.1	94.2
139	do	B. R. M.	95.1	87.2	45.0	98.4	88.3
140	do	A. J. P.	97.0	92.2	89.6	98.2	90 8
141	do	O. W. K.	96.9	92.1	91.2	98.1	90.8
146	do	O. W. K.	98.7	97.7	99.1	98.9	94.7
	Average of Nos. 129, 130, 138, 140, 141.		*a* 97.0	89.4	*b* 80.4	98.2	90.5
	Average of all (13)		96.0	86.4	73.5	98.3	91.1

a Not including No. 130.

TABLE 29.—*Digestibility of nutrients and energy of bread alone*—Continued.

Number of experiment.	Kinds of food.	Subject.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Heat of combustion.
			Per ct.	*Per ct.*	*Per ct.*	*Per cent.*	*Per cent.*
131	Graham bread	C. W. S	89.9	77.5	51.3	92.4	84.8
132	....do	F. H. M	89.8	77.0	36.3	93.2	84.8
133	....do	C. D. H	89.6	79.3	54.7	92.3	85.2
134	....do	P. F. F	87.1	70.3	37.9	91.2	82.4
144	....do	A. J. P	90.7	80.7	83.9	92.7	85.1
145	....do	O. W. K	98.9	77.3	84.6	92.5	84.3
	Average of Nos. 131, 134, 144, 145.		91.7	76.5	64.4	92.2	84.2
	Average of all (6)		91.0	77.0	58.1	92.4	84.4
135	Entire wheat bread	C. W. S	....	79.2	....	96.0	87.1
136	....do	P. F. F	96.1	88.6	48.4	97.9	91.6
137	....do	A. B. O	94.7	86.3	10.4	96.9	90.0
142	....do	A. J. P	95.4	88.8	84.0	97.3	89.3
143	....do	O. W. K	96.4	90.4	88.2	98.0	90.0
	Average of Nos. 135, 136, 142, 143.		*a* 96.0	86.8	*a* 73.5	97.3	89.5
	Average of all (5)		95.7	86.7	57.8	97.2	89.6

a Not including No. 135.

As previously stated (p. 15), it is a matter of common observation that digestion experiments made with one kind of food material do not give on the whole as reliable results as those in which two or more food materials are used. In other words, it appears that with a mixed diet the same person will digest a larger proportion of nutrients than with a diet composed of a single food material. Thus, as shown in a recent compilation, the average of 10 experiments with an exclusively milk diet[1] gave 92.1 per cent as the amount of protein and 86.3 per cent as the amount of carbohydrates which was digestible. Five experiments made with an exclusively bread diet or with bread and sugar showed 82 per cent of the protein and 99 per cent of the carbohydrates to be digested. Five experiments with a diet of bread and milk showed 97 per cent of the protein and 98.7 per cent of the carbohydrates to be digested. In other words, the protein in milk alone or in bread alone seems to be much less completely digested than when the two are eaten together. For this reason in the majority of digestion experiments milk was consumed ad libitum with bread. Small amounts of butter and sugar were also eaten. The greater coefficient of digestibility of bread and milk as compared with that of bread alone is shown by the comparison of the results of experiments Nos. 123–126 with those of experiments Nos. 127–130.

METABOLIC PRODUCTS IN FECES.

It has already been said that the feces are not made up entirely of undigested residue of food, but contain quite large amounts of other waste materials. These materials, the "Stoffwechselproducte" of German investigators, are usually designated by English writers as metabolic products. This term as ordinarily used includes, however, not only the metabolic products, strictly speaking, such as the residues from the bile, mucus, saliva, gastric juices, pancreatic juices, and other digestive secretions, but also includes worn-out particles from the mucus membrane lining the intestines, and other débris from the walls of the stomach, etc. The results of the recent investigations indicate that the digestion of food materials is more complete and the proportion of metabolic products in the feces is larger than was formerly supposed. It is not at all improbable that during the processes of natural digestion, aided by careful preparation of the food and proper mastication, practically all of the nutrients of most foods are rendered absorbable in the alimentary canal and that undigested residues are rather accidental than incidental. Much study is now being given to this subject and attempts are being made by chemical and microscopical methods to determine the amounts of metabolic products excreted daily in the feces. In view of the importance of this kind of work, the metabolic nitrogen of the feces was studied in the experiments above reported and in two supplementary experiments in which the subject consumed no nitrogenous food. These results are reported without any extended discussion as a contribution to the knowledge of the question of the amount of metabolic nitrogen in the feces. Such experiments are being continued, and when more data have been accumulated and a review of the literature of this subject can be prepared, a general discussion of this question may be in order.

---

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 21, p. 61, and Connecticut Storrs Sta. Rpt. 1896, p. 163.

In the experiments at the Maine Station various chemical and physical methods have been adopted for determining the metabolic products in the feces. The quantity of such material may be approximately learned (1) by treating the feces with certain solvents; (2) by determining the amount of nitrogen in the feces during a carbohydrate diet; and (3) by determining the amount and composition of feces during complete or partial fasting.

TREATMENT OF FECES WITH PEPSIN SOLUTION.

Grouven as early as 1867 observed in experiments with animals that the feces sometimes contain more nitrogen than the food ingested. Schulze and Maercker[1] attempted to determine the amount of metabolic nitrogen by separating it from the feces with boiling alcohol and boiling ether. For several years this method was employed, but was shown by different investigators to be unreliable. In 1885 Stutzer[2] proposed to dissolve out the metabolic nitrogenous matter by digesting it with freshly prepared pepsin solution. This method was modified and improved upon by Pfeiffer,[3] and in general has been followed in this country at the Maine, New York, Maryland, and other agricultural experiment stations where such work has been carried on. The method is described in earlier publications of the Maine Station.[1] In the same publications a modified method for determining metabolic nitrogen by treating the feces with ether, alcohol, water, and limewater is described.

---

[1] Jour. Landw., 19 (1871), p. 46.

[2] Ztschr. Physiol. Chem., 10 (1886), p. 153.

[3] Ztschr. Physiol. Chem., 10 (1886), pp. 170 and 561, and Jour. Landw., 34 (1886), p. 425.

A portion of the feces in digestion experiments Nos. 127–146, inclusive, described above, was treated with pepsin solution according to the usual method. This solution was prepared by dissolving 1.25 grams German plain soluble pepsin in 1 liter of 0.2 per cent hydrochloric acid, made by adding 20 cubic centimeters of a solution containing exactly 10 per cent hydrochloric acid gas to 1 liter of water, and adding 5 cubic centimeters of a solution of thymol in alcohol as a preservative. A weighed sample of finely ground feces was placed in a beaker with 200 cubic centimeters of this solution, which had previously been heated to 50° C. The whole was placed in a water bath at 40° C. for eight hours on two successive days. At intervals of two hours 1 cubic centimeter of 10 per cent hydrochloric acid was added until the final strength of the solution was 0.5 per cent. On the day following the second digestion the solution was decanted upon folded filters. The residue was washed by decantation and also upon the filter until no proteids were obtained on testing the wash water. The filter and contents were dried. As much as possible of the top of the filter was cut off. The nitrogen in the dried material, which was assumed to represent the nitrogen of undigested material, was determined by the Kjeldahl method, a suitable correction being made in the results for the small amount of nitrogen of the filter paper. The results obtained by this method, as applied to the feces in experiments Nos. 123–127, are shown in Table 30.

TREATMENT OF FECES WITH ETHER, ALCOHOL, HOT WATER, AND COLD LIMEWATER.

As has already been stated, the method of determining the amount of metabolic nitrogen in feces by treatment with ether, alcohol, hot water, and cold limewater has been in use at the Maine Station for some years. The method of manipulation is as follows:

One gram of finely ground feces is boiled for one-half hour with 25 cubic centimeters water-free ether in a small flask with a reversed condenser, the ether decanted upon a filter, and the operation repeated. After washing with ether by decantation, 50 cubic centimeters of 95 per cent alcohol is poured upon the residue of the feces in the flask and boiled for 10 minutes, a reversed condenser being used, as before. The alcohol is decanted upon the same filter as was used for the ether extract and the whole washed with hot alcohol. The sample of feces is then heated on a steam bath for 20 minutes with 50 cubic centimeters of water and the whole washed with hot water upon the same filter as before. Feces and filter are then placed in a beaker with 50 cubic centimeters of limewater (a saturated solution), and allowed to stand for 6 hours. The whole is then thoroughly washed upon a fresh filter with dilute limewater and, after drying, the nitrogen determined in the residue by the Kjeldahl method, a correction being applied for the nitrogen in the filters. The results of this method of making correction for the metabolic nitrogen of feces in the digestion experiments Nos. 123–146 are also shown in Table 30.

---

[1] Maine Sta. Rpts. 1887, p. 128; 1888, p. 210; and 1889, p. 282.

The table showing the correction obtained by the two methods includes the total weight of partially dried feces, the percentage nitrogen in this material and in the residue of feces not dissolved by treatment with pepsin or with ether, alcohol, and limewater. Various results computed with the aid of these figures and those given in Tables 4–27 are also shown.

TABLE 30.—*Digestible nitrogen corrected for metabolic nitrogen of feces determined by treatment with pepsin solution and by extraction with ether, alcohol, hot water, and limewater.*

	Nitrogen in food.	Weight of feces.[a]	Nitrogen in feces.		Treatment with pepsin.				Treatment with ether, alcohol, hot water, and limewater.			
					Nitrogen of feces undissolved by treatment.		Nitrogen digested.		Nitrogen of feces undissolved by treatment.		Nitrogen digested.	
	Gms.	*Gms.*	*P. ct.*	*Gms.*	*P. ct.*	*Gms.*	*Gms.*	*P. ct.*	*P. ct.*	*Gms.*	*Gms.*	*P. ct.*
Digestion experiment No. 123, with white bread: Entire diet (=bread alone)	22.94	41.0	5.10	2.10	2.11	0.87	22.07	96.21	3.88	1.60	21.34	92.60
Digestion experiment No. 124, with white bread: Entire diet (=bread alone)	13.28	34.0	7.83	2.66	2.30	.78	12.50	94.19	3.76	1.28	12.00	90.37
Digestion experiment No. 125, with white bread: Entire diet (=bread alone)	15.01	50.0	6.66	3.33	2.79	1.39	13.62	90.74	4.29	2.14	12.87	85.74
Digestion experiment No. 126, with white bread: Entire diet (=bread alone)	14.93	46.0	8.00	3.68	2.32	1.07	13.86	92.90	3.88	1.78	13.15	88.07
Digestion experiment No. 127, with white bread and milk:												
Entire diet	24.24	56.0	5.86	3.28	2.71	1.52	22.72	93.73	4.46	2.50	21.74	89.70
Bread alone	15.20	......	......	3.10	......	1.44	13.76	90.55	.....	2.36	12.84	84.49
Digestion experiment No. 128, with white bread and milk:												
Entire diet	27.60	56.0	4.53	2.54	1.52	.85	26.75	96.92	3.27	1.83	25.77	93.37
Bread alone	13.42	......	......	2.26	......	.76	12.66	94.37	......	1.63	11.79	87.89
Digestion experiment No. 129, with white bread and milk:												
Entire diet	50.14	84.0	4.82	4.05	1.70	1.43	48.71	97.15	3.06	2.57	47.57	94.89
Bread alone	31.02	......	......	3.66	......	1.30	29.72	95.80	......	2.33	28.69	92.50
Digestion experiment No. 130, with white bread and milk:												
Entire diet	36.90	82.0	4.89	4.01	1.59	1.30	35.60	96.47	3.45	2.83	34.07	92.35
Bread alone	18.19	......	......	3.63	......	1.18	17.01	97.08	......	2.57	15.62	85.88
Digestion experiment No. 131, with Graham bread and milk:												
Entire diet	51.64	168.0	3.75	6.30	1.52	2.55	47.09	95.09	2.97	4.99	46.65	90.37
Bread alone	25.76	......	......	5.79	......	2.34	23.42	90.93	......	4.58	21.18	82.22

[a] This represents the weight of the feces "partially dry." For explanation of method of partial drying, see U. S. Dept. Agr., Office of Experiment Stations Bul. 44, p. 24.

TABLE 30.—*Digestible nitrogen corrected for metabolic nitrogen of feces determined by treatment with pepsin solution and by extraction with ether, alcohol, hot water, and limewater*—Continued.

	Nitrogen in food.	Weight of feces.	Nitrogen in feces.		Treatment with pepsin.				Treatment with ether, alcohol, hot water, and limewater.			
					Nitrogen of feces undissolved by treatment.		Nitrogen digested.		Nitrogen of feces undissolved by treatment.		Nitrogen digested.	
	Gms.	*Gms.*	*P. ct.*	*Gms.*	*P. ct.*	*Gms.*	*Gms.*	*P. ct.*	*P. ct.*	*Gms.*	*Gms.*	*P. ct.*
Digestion experiment No. 132, with Graham bread and milk:												
Entire diet	39.12	115.0	3.86	4.44	1.65	1.90	37.22	95.13	2.75	3.16	35.96	91.93
Bread alone	17.36	......	......	4.00	......	1.72	15.64	90.10	......	2.85	14.51	83.60
Digestion experiment No. 133, with Graham bread and milk:												
Entire diet	45.05	108.0	3.38	3.65	1.03	1.11	43.94	97.55	2.48	2.68	42.37	94.05
Bread alone	15.36	......	......	3.04	......	.93	14.43	93.95	......	2.23	13.13	85.48
Digestion experiment No. 134, with Graham bread and milk:												
Entire diet	42.80	150.0	3.65	5.48	1.20	1.80	41.00	95.80	2.52	3.78	39.02	91.19
Bread alone	16.69	......	......	4.94	......	1.63	15.06	90.23	......	3.42	13.27	79.50
Digestion experiment No. 135, with entire wheat bread and milk:												
Entire diet	45.21	104.0	4.74	4.93	1.83	1.90	43.31	95.80	3.50	3.64	41.57	91.97
Bread alone	21.34	......	......	4.45	......	1.72	19.62	96.35	......	3.29	18.05	84.58
Digestion experiment No. 136, with entire wheat bread and milk:												
Entire diet	58.07	82.0	4.55	3.73	1.34	1.10	56.97	98.10	3.47	2.84	55.23	95.10
Bread alone	27.36	......	......	3.12	......	.92	26.44	96.65	......	2.38	24.98	91.30
Digestion experiment No. 137, with entire wheat bread and milk:												
Entire diet	49.52	88.0	4.10	3.61	1.20	1.06	48.46	97.85	2.73	2.40	47.12	95.15
Bread alone	22.24	......	......	3.06	......	.90	21.34	95.95	......	2.04	20.20	90.83
Digestion experiment No. 138, with white bread and milk:												
Entire diet	41.49	36.0	4.17	1.50	1.16	.42	41.07	99.00	2.75	.99	40.50	97.65
Bread alone	19.28	......	......	1.06	......	.30	18.98	98.47	......	.70	18.58	96.39
Digestion experiment No. 139, with white bread and milk:												
Entire diet	42.24	82.4	4.39	3.62	.92	.76	41.48	98.20	1.78	1.47	40.77	95.55
Bread alone	21.14	......	......	3.09	......	.65	22.49	93.17	......	1.26	22.88	94.79
Digestion experiment No. 140, with white bread and milk:												
Entire diet	37.87	45.8	3.79	1.74	1.09	.50	37.87	98.67	2.55	1.17	36.70	96.93
Bread alone	16.42	......	......	1.31	......	.37	16.42	97.80	......	.88	15.91	94.77
Digestion experiment No. 141, with white bread and milk:												
Entire diet	37.39	43.8	3.94	1.73	1.27	.56	36.83	98.50	2.73	1.20	36.19	96.80
Bread alone	16.32	......	......	1.30	......	.47	15.90	97.43	......	.89	15.43	94.55
Digestion experiment No. 142, with entire wheat bread and milk:												
Entire diet	31.10	60.0	3.92	2.35	1.45	.87	30.23	97.19	2.77	1.66	29.44	94.65
Bread alone	18.82	......	......	2.11	......	.78	18.04	95.86	......	1.48	17.34	92.10
Digestion experiment No. 143, with entire wheat bread and milk:												
Entire diet	30.33	50.6	4.36	2.21	1.45	.74	29.59	97.57	2.78	1.41	28.92	95.39
Bread alone	18.00	......	......	1.74	......	.66	17.34	96.33	......	1.25	16.75	93.05
Digestion experiment No. 144, with Graham bread and milk:												
Entire diet	30.84	115.4	3.26	3.76	1.31	1.51	29.33	95.09	2.24	2.58	28.26	91.57
Bread alone	18.13	......	......	3.50	......	1.41	16.72	92.22	......	2.41	15.72	86.92
Digestion experiment No. 145, with Graham bread and milk:												
Entire diet	28.55	96.8	3.64	3.52	1.27	1.23	27.32	95.72	2.61	2.52	26.03	91.19
Bread alone	14.26	......	......	3.23	......	1.13	13.13	92.07	......	2.31	11.95	83.82
Digestion experiment No. 146, with white bread and milk:												
Entire diet	17.81	13.0	2.87	.37	1.47	.19	17.62	98.99	......	.32	17.49	98.20
Bread alone	8.21	......	......	.19	......	.09	8.12	98.90	......	.16	8.05	98.05

The explanation of these tables is, perhaps, best illustrated by discussing experiment No. 127 in detail, which is chosen because it is the first in which some other food was taken in addition to bread. During the two days of this experiment the total feces partially dried weighed 56 grams. This contained 5.86 per cent nitrogen, making a total of 3.28 grams of nitrogen thus eliminated. By treatment with pepsin 3.15 per cent of the nitrogen of the feces was dissolved, leaving 2.71 per cent nitrogen undissolved. By treating the feces with ether, alcohol, hot water, and limewater according to the second method mentioned, 4.46 per cent nitrogen was left undissolved. The total nitrogen not dissolved by treatment with pepsin amounted to (56×2.71=) 1.52 grams, and that not dissolved by treatment with ether, alcohol, hot water, and limewater amounted to (56×4.46=) 2.50 grams. The quantity of nitrogen in the feces from bread alone was estimated as 16 per cent of the protein of the feces from bread (19.4×16=3.10). The nitrogen not dissolved by treatment, in the feces from bread alone, described above, is obtained by assuming that the ratio of metabolic nitrogen to total nitrogen in the feces from bread would be the same as the ratio of metabolic nitrogen to the total nitrogen in the feces from the entire diet. In other words, it was assumed that the total nitrogen in the feces bears the same relation to the total nitrogen in the feces from bread alone that the total nitrogen not dissolved by treatment bears to the nitrogen not dissolved in the feces from bread alone. Thus, in experiment No. 127 (see p. 17), the nitrogen in the feces from bread not dissolved by treatment with pepsin is 1.44, computed according to the following proportion: 3.28 : 1.52 : : 3.10 : 1.44. In the same way the nitrogen in the feces from bread not dissolved by treatment with ether, alcohol, hot water, and limewater is 2.36, obtained according to the proportion 3.28 : 2.50 : : 3.10 : 2.36. According to the above assumption the proportion of metabolic products from the digestion of milk and other foods besides bread would be the same as from the digestion of bread itself. While we have no definite warrant for this assumption, the results can be but slightly affected by considerable variations in the relative amounts, owing to the small quantity of nitrogen in the feces from these other foods. The nitrogen in the total food eaten and in the bread is obtained by taking 16 per cent of the corresponding values for protein, as shown in the details of this experiment given in Table 8 on page 17. The amounts actually digested are obtained by subtracting the nitrogen not dissolved by treatment with pepsin or by treatment with ether, alcohol, hot water, and limewater from the total nitrogen in the food eaten, while the percentages actually digested are computed in the usual way by dividing the amounts actually digested by the amounts in the total food. It is of course evident that the coefficients of digestibility of protein would be the same as those for nitrogen.

METABOLIC NITROGEN IN THE FECES ON A CARBOHYDRATE DIET AND DURING FASTING.

During the past fifteen years a number of investigators have studied the amount and composition of the feces when a diet limited to carbohydrates was consumed, and during periods of partial or complete fasting, since it was believed that if no nitrogen was consumed, that obtained in the feces must be nitrogen of metabolic products. Very many of the experiments of this nature have been made with lower animals, especially dogs. While many important observations and deductions have been obtained by these studies, the results after all have thrown but little light on the amount of metabolic nitrogen normally present in the feces. Voit found, in experiments with a dog having a biliary fistula, that three times as much bile was discharged when a meat diet was consumed as when fasting. It was observed further that the amount of feces from a meat diet was not proportional to the quantity of meat eaten, as must be the case if the feces were composed solely of undigested food. As a matter of fact the weight of the feces when 600 grams of meat was eaten daily was only 2 grams greater than the quantity obtained when the dog fasted.

Carbohydrate diet.—In order to determine the amount of nitrogen in the feces when little or no nitrogen was ingested in the food, an experiment of two days' duration was carried on with a healthy man—the subject of Experiment No. 123, previously reported (p. 13)—in which the food consisted of tapioca. This was allowed to soak in water over night, was then cooked to a paste, and eaten with sugar, salt, and a little flavoring matter. The air-dry tapioca contained 11.97 per cent water. The percentage composition of the water-free tapioca was as follows: Protein 0.79, carbohydrates 98.90, and ash 0.31. The sugar was assumed to be pure, and therefore nitrogen-free.

The same amount of carbohydrates was taken as in digestion experiment No. 123 with wheat bread, namely, 861.1 grams (see Table 4). The fresh feces during the two days weighed 131.4 grams. The partially dried feces weighed 19 grams, and contained 6.5 per cent of nitrogen. The assumption seems warranted that this was all nitrogen of metabolic products. Theoretically all the nitrogenous metabolic products in the feces should be soluble in a pepsin solution. As a matter of fact only 69.4 per cent of the nitrogen in the feces from this nitrogen-free diet was rendered soluble by a pepsin solution, while ether, alcohol, hot water, and limewater extracted only 43.7 per cent of it. The results of these experiments are given in Table 33.

Fasting.—The composition of the feces during fasting is not well known. Five experiments with man along these lines have been reported and have been summarized together with the results of other metabolism experiments in a recent bulletin of this Office.[1]

For the purpose of obtaining information upon the question of the amount and composition of the feces during fasting, an experiment of two days' duration was made, during which time no food whatever was eaten. The feces were marked at the beginning and end of the experimental period with milk and charcoal, as usual. The feces excreted each day were kept separate, as was also the urine. There was almost no difference in the amount and composition of the feces on the two days. During the first day 534.1 grams of urine was excreted, containing 2.04 per cent of nitrogen, and on the second day 522.3 grams, containing 2.49 per cent of nitrogen, or about 2 grams more than on the first day.

Table 33 summarizes the results of this experiment and that in which the diet consisted of carbohydrates, and includes for purposes of comparison the results obtained in experiments Nos. 123 and 124 with the same subject, when bread only was eaten.

Experiment No. 146, reported on page 30, was carried on with an insufficient amount of food, and is called a "partial fasting experiment." This and No. 141 with the same subject on a full diet of the same articles are also included for purposes of comparison. The subject of these experiments was not the same as in the other experiments shown in the table, and perhaps the results are, therefore, not strictly comparable.

No explanation of the figures in the table is required, unless it be of those in the last column headed "Protein oxidized." These were computed from the nitrogen in the urine on the supposition that this nitrogen is a measure of the amount of protein broken down in the body, and that this protein contained 16 per cent nitrogen.

TABLE 31.—*Comparison of protein metabolized and nitrogen excreted in the feces, with different diets and during fasting.*

Kind of experiment.	Subject.	Total weight.	Amount carbohydrates.	Nitrogen.		Protein oxidized.
Bread diet (No. 123).	H. B. S.	*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Grams.*
Income: Bread		816.5	430.5	1.40	11.43	
Outgo:						
Feces (partially dried)		20.3		5.18	1.06	
Urine		1,071.0		1.81	19.38	121.1
Total					20.44	
Bread diet (No. 124).	H. B. S.					
Income: Bread		478.0	260.2	1.39	6.64	

---

[1] See summary of these experiments and those in which the diet consisted of nitrogen-free materials in U. S. Dept. of Agr., Office of Experiment Stations Bul. 45, pp. 88, 68, and 78.

TABLE 21.—*Comparison of protein metabolized and nitrogen excreted in the feces, with different diets and during fasting*—Continued.

Kind of experiment.	Subject.	Total weight.	Amount carbohydrates.	Nitrogen.		Protein oxidized.
Bread diet (*No. 124*)—Continued.	H. B. S.					
Outgo:		*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Grams.*
Feces (partially dried)		17.0		7.83	1.33	
Urine		775.0		1.20	9.28	58.0
Total					10.61	
Carbohydrate diet.	H. B. S.					
Income:						
Tapioca		194.4	174.1	.79	1.40	
Sugar		256.4	256.4			
Total			430.5		1.40	
Outgo:						
Feces (partially dried)		9.5		6.50	.62	
Urine		1,597.6		.48	7.67	47.9
Total					8.29	
Fasting.	H. B. S.					
Outgo:						
Feces		8.0		5.44	.44	
Urine		528.2		2.27	11.96	74.8
Total					12.40	
Mixed diet (*No. 146*). *Partial fasting.*	O. W. K.					
Income:						
Bread		284.0		1.45	4.12	
Milk		814.8		.58	4.73	
Butter		33.9		.20	.68	
Sugar		20.1				
Total			201.1		9.53	
Outgo:						
Feces (partially dried)		6.5		2.87	.19	
Urine		765.0		1.58	12.08	75.5
Total					12.27	
Mixed diet (*No. 141*).	O. W. K.					
Income:						
Bread		568.8		1.43	8.13	
Milk		1,100.0		.53	5.83	
Do		800.0		.57	4.56	
Butter		67.8		.22	.15	
Sugar		40.2				
Total			424.4		18.67	
Outgo:						
Feces (partially dried)		21.9		3.94	.86	
Urine		1,265.0		1.25	15.81	98.8
Total					16.67	

The power of carbohydrates to protect protein from cleavage in the body becomes apparent when the amount of protein metabolized on the carbohydrate diet, as shown by the last column in the table, is compared with the corresponding amount during the period of fasting. During this latter period 50 per cent more body protein was oxidized than was the case during the period in which carbohydrates were eaten. The minimum cleavage of protein in the body in these tests was not reached during fasting, as Voit claims may be done, since with a carbohydrate diet a much smaller cleavage of protein was found. This is in accord with the results obtained by Munk. As regards the metabolized nitrogen of metabolic products in the feces, it will be seen that there was more nitrogen in the feces during the period on a carbohydrate diet than during either period on the bread diets. This would seem to indicate that a very large part of the nitrogen in the feces from an ordinary diet is due to metabolic products required for the digestion of the various nutrients of the food. Even in fasting, when no digestive juices were required by the presence of food in the intestinal tract, a considerable amount of nitrogen was eliminated in the urine, amounting to one-third the amount found when a bread diet was eaten. The data obtained are regarded as insufficient for other and more general deductions, and as the authors are continuing their experiments, no further discussion will be attempted at present.

ARTIFICIAL DIGESTION OF BREAD WITH PEPSIN.

In 1880 Stutzer[1] published the results of an investigation upon the solubility of proteids in pepsin solution, from which he concluded that he had found a method for determining the digestible proteids of food with great exactness. Pfeiffer,[2] Kühn,[3] Wolff,[4] and especially Stutzer,[5] during the next ten years made exhaustive and comparative studies of the conditions and methods best adapted for the artificial digestion of proteids. The method thus elaborated and brought into general use is described by Wiley,[6] and is practically the method used in the following experiments. After tests with various sorts, the German plain pepsin was selected for the experiments. It is fully as active as any, gives a clear solution, and is free from proteids. The pepsin solution was prepared by dissolving 1.25 grams pepsin in 1 liter of 0.2 per cent of hydrochloric acid. In earlier work at the station a stronger solution was used, but repeated tests showed that for 1 gram of bread a solution containing 1.25 grams pepsin to the liter proved as efficient as the stronger solution, or, indeed, as one containing four times that amount. The manipulation was practically the same as that noted above in describing the treatment of feces with pepsin solution to learn the amount of true undigested protein present. The bread was prepared for analysis by drying and grinding in the usual way; that is, the material was in the condition known as "partially dry." Two hundred cubic centimeters of the pepsin solution was added to 1 gram of bread in a suitable beaker, stirred thoroughly, and placed in a water bath heated to 50° or 60° C. The digestion was begun at 8 o'clock in the morning, and was continued for eight hours on two consecutive days, fresh hydrochloric acid being added every two hours. The beaker was then allowed to stand over night, and on the following morning the supernatent liquid was decanted upon folded filters, the residue washed by decantation, transferred to the filter, and again the whole washed until no proteids could be obtained on testing the filtrate. The filter and contents were then dried and the nitrogen determined by the usual method, a suitable correction being made for the nitrogen of the filter paper.

---

[1] Jour. Landw., 28 (1880), pp. 195, 435.

[2] Ztschr. Physiol. Chem., 10 (1886), p. 561; 11 (1887), p. 1.

[3] Landw. Vers. Stat., 44 (1894), p. 188.

[4] Landw. Jahrb., 19 (1890), p. 842.

[5] Ztschr. Physiol. Chem., 9 (1885), p. 211; 10 (1886), p. 156; 11 (1887), p. 361; Jour. Landw., 29 (1881), p. 478.

[6] Principles and Practice of Agricultural Analysis, vol. 3, p. 555.

Using this method, tests were made of the digestibility of 12 samples of white bread, 5 samples of whole wheat bread, and 6 samples of Graham bread. The results obtained are shown in Table 32.

TABLE 32.—*Digestibility of breads of different sorts by pepsin solution.*

Laboratory number.	Kind of bread.	Nitrogen.			
		In bread.	In undigested portion.	In digested portion.	Coefficient of digestibility.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
6001	White bread	2.04	0.06	1.98	97.06
6002	.....do	1.95	.06	1.89	96.92
6003	.....do	1.95	.20	1.75	89.72
6004	.....do	1.95	.20	1.75	89.72
6005	.....do	1.99	.13	1.86	93.47
6006	.....do	2.02	.13	1.89	93.57
6007	.....do	2.32	.17	2.15	92.67
6064	.....do	2.22	.15	2.07	93.25
6065	.....do	2.23	.15	2.08	93.29
6077	.....do	2.19	.15	2.04	93.15
6078	.....do	2.19	.14	2.05	93.62
6120	.....do	2.23	.15	2.08	93.27
	Average	2.11	.14	1.97	93.37
6047	Whole wheat bread	2.18	.17	2.01	92.20
6048	.....do	2.19	.18	2.01	91.67
6049	.....do	2.17	.17	2.00	92.15
6086	.....do	2.33	.23	2.10	90.13
6087	.....do	2.31	.20	2.11	91.34
	Average	2.24	.19	2.05	91.50
6034	Graham bread	2.11	.28	1.83	86.74
6035	.....do	2.08	.28	1.80	86.35
6036	.....do	2.09	.27	1.82	87.10
6037	.....do	2.03	.25	1.78	87.69
6097	.....do	1.91	.25	1.66	86.92
6098	.....do	1.98	.26	1.72	86.87
	Average	2.03	.27	1.77	86.94

COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF PROTEIN IN BREAD AS DETERMINED BY DIFFERENT METHODS.

Table 33 summarizes the results obtained by the different methods for determining the actual digestibility of the protein in different kinds of bread. In the column headed "artificial digestion" are the results obtained by digesting bread with pepsin in the manner just described. The figures in the column headed "natural digestion" show the coefficients of digestibility of the bread obtained in the experiments with man, reported in Tables 4–27. In the following column are shown the results of the natural-digestion experiments when corrections are introduced, which were obtained by treating the feces with pepsin solution; and in the last column the results when corrections are introduced obtained by treating the feces with ether, alcohol, hot water, and limewater. It will be remembered that the attempt was made to determine the metabolic products by these two methods and thus learn the actual, rather than the apparent, coefficients of digestibility of bread.

TABLE 33.—*Digestibility of nitrogen (or protein) of different kinds of bread as determined by different methods.*

Experiment number.	Kind of bread.	Laboratory number.	Artificial digestion.	Natural digestion.	Natural digestion, with correction obtained by pepsin method.	Natural digestion, with correction obtained by ether, alcohol, hot water, and limewater method.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
123	White bread	6001	96.85	90.87	96.21	92.60
124	.....do	6002	96.92	80.00	94.13	90.37
125	.....do	6003	89.72	81.68	90.74	85.74
126	.....do	6004	89.88	75.35	92.90	88.07
127	.....do	6005	93.47	79.61	90.55	84.49
128	.....do	6006	93.57	83.16	94.37	87.89
129	.....do	6007	92.67	88.18	95.80	92.50
130	.....do	6007	92.67	80.07	97.08	85.88
138	.....do	6064	93.25	94.51	98.47	96.39
139	.....do	6065	93.29	87.18	93.17	94.79
140	.....do	6077	93.15	92.22	97.80	94.77
141	.....do	6078	93.62	92.10	97.43	94.55
a146	.....do	6120	96.29	97.66	98.90	98.05
	Average		93.26	85.41	94.72	90.67
135	Whole wheat bread	6047	92.20	79.15	96.35	84.58
136	.....do	6048	91.67	88.60	96.65	91.30
137	.....do	6049	92.15	86.27	95.95	90.83
142	.....do	6086	90.13	88.81	95.86	92.10
143	.....do	6087	91.34	90.35	96.33	93.05
	Average		91.49	88.63	96.22	90.37
131	Graham bread	6034	86.74	77.54	90.93	82.22
132	.....do	6035	86.35	76.98	90.10	83.60
133	.....do	6036	87.10	79.34	93.95	85.48
134	.....do	6037	87.69	70.32	90.23	79.50
144	.....do	6097	86.92	80.66	92.22	86.92
145	.....do	6098	87.07	77.33	92.07	83.82
	Average		86.97	77.02	91.58	83.88

a A period of partial fasting. This experiment not included in the average.

It will be seen that there are considerable differences in the values for the digestibility of the protein of bread as determined by the natural method when the corrections for metabolic products made according to the two ways are introduced. The values obtained by the use of the ether, alcohol, and limewater method give a much lower coefficient of digestibility than those obtained by correcting with the pepsin solution method. The coefficients of digestibility of the protein of white bread as obtained by artificial digestion agree quite nearly with those obtained by natural digestion when corrections are introduced obtained by determining the metabolic products in the feces by treatment with a pepsin solution. On the other hand the coefficients of digestibility of the whole wheat bread as determined by artificial digestion accord more nearly with the results of natural digestion experiments when corrections are introduced obtained by determining the metabolic products by treatment with ether, alcohol, hot water, and limewater. With Graham bread the coefficients of digestibility obtained by artificial digestion are very nearly a mean between the results obtained by the natural digestion with suitable corrections introduced for metabolic nitrogen, as determined by the pepsin method and by the ether alcohol and limewater method.

The results thus far obtained are insufficient for general conclusions. They indicate, however, that none of the methods employed was entirely satisfactory. Experiments along the same line are now being carried on, and it is the author's intention to discuss the subject more fully when the results of these experiments are reported.

SKIM MILK VERSUS WATER IN BREAD MAKING.

At the dairy meeting of the Maine board of agriculture in 1897 a paper[1] was presented by one of the authors of this bulletin in which emphasis was laid upon the importance of skim milk as food. In discussing the value of this material the following statements were made:

> The value of skim milk as food on the farm is not generally appreciated. Taken by itself, it is rather thin and, as people say, does not "stay by." The reason for this is simple; one has to drink a large quantity to get the needed nourishment, and further it is so readily disposed of that it does not satisfy the sense of hunger. But when eaten with bread, or used in cooking, it is a food material the value of which is not at all appreciated by the farmer. A pound of lean beef contains about 0.180 pound of flesh formers, and has a fuel value of 870 calories. Two quarts and a half, or 5 pounds, of skim milk will furnish the same amount of flesh formers, and have nearly the same fuel value as a pound of round steak. Two quarts of skim milk has 0.14 pound of flesh formers, and a fuel value of 680 calories, while this quantity of oysters contains only 0.12 pound of flesh formers, and a fuel value of 470 calories.
>
> A few of the ways in which skim milk may be used in cooking are as follows: In the preparation of soups such as potato, celery, tomato, green pea, and green corn soups; fish, lobster, clam, and oyster chowders, bisque and stews, skim milk will equally well replace the whole milk that the directions for preparation usually call for. Skim milk makes as good white soup as whole milk. Bread mixed with skim milk is more nutritious than that made with water, while all kinds of quick biscuit, griddle cakes, etc., can be made with skim milk as well as with whole milk. In most kinds of cake skim milk will be found a perfect substitute for whole milk. If the skim milk is sour, so much the better for cake and quick bread making, as only half the cream of tartar called for in the recipe will be needed. Sweet skim milk can be used to advantage in making rice and Indian puddings, custards, squash and pumpkin pies, and the like, in the preparation of chocolate or cocoa as a drink, in the making of sherbets and other ices, and in dozens of other ways which will readily occur to housekeepers.

---

[1] Agriculture of Maine, 1897, p. 216.

In the above quotation the statement that bread baked from dough mixed with skim milk is more nutritious than that from dough mixed with water was based upon a knowledge of the composition of skim milk rather than upon exact experimental evidence, since at that time, so far as could be learned, no experiments on this subject had been reported. A short time ago the British Dairy Farmers' Association awarded prizes for bread made with skim milk instead of water. In a recent report of the society[1] the chemical composition of two samples of bread made with water and two made with skim milk were recorded. These were as follows:

TABLE 34.—*Composition of the dry matter of water bread and skim-milk bread.*

	Dry matter.	In dry matter.			
		Protein.	Fat.	Carbohydrates.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water bread	60.64	12.05	0.20	87.27	0.48
Do	62.80	15.43	.29	82.37	1.91
Average		13.74	.25	84.82	1.19
Skim-milk bread	61.36	14.98	.83	83.73	.46
Do	69.56	14.72	1.15	80.97	3.16
Average		14.85	.99	82.35	1.81

There is nothing in the report to show that the same flour was used in the different samples, and indeed from the analyses it would seem as though this were not the case. It will be noticed that the protein in the second water bread was higher than in either of the skim-milk breads, and as is shown by the results of investigations reported beyond, this would hardly be true if the same kind of flour were used for both kinds of bread. The higher percentages of fat must be accounted for by the addition of shortening or by the milk being only partially skimmed.

Owing to a belief in the value of skim milk in bread making and to the lack of accurate information on the subject, three experiments were undertaken at the Maine Station. In each experiment four double loaves of bread were made from the same flour, two from dough mixed with water, and two from dough mixed with skim milk. The work was done by a practical bread maker, who used her own formulas, no conditions being imposed except that skim milk should be used in one case and water in the other. The quantities of the materials required were estimated, as is perhaps generally the case when bread is made in the household. They were weighed, however, before being used.

Table 35 shows the quantities of the ingredients used in the different experiments.

---

[1] Jour. British Dairy Farmers' Assn., 14 (1899), pt. 2, pp. 93–97.

TABLE 35.—*Weight of materials used in the different lots of bread.*

Ingredients.	Water bread.			Skim-milk bread.		
	No. 6115.	No. 6118.	No. 6190.	No. 6116.	No. 6119.	No. 6191.
	Grams (a)	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Flour	782	876	1,287	752	886	1,241
Salt	8	9	10	9	15	10
Sugar	31	24	25	26	26	25
Lard	14	21	15	10	23	15
Yeast	4	4	5	4	4	5

[a] One ounce equals 28.35 grams, or, in round numbers, 30 grams; 100 grams equals 3.5 ounces.

It will be seen that the amount of the flour and other ingredients varied within somewhat wide limits in the different experiments, but it is probable that the variation was not greater than in ordinary household practice.

The bread was mixed in the early evening and baked the next morning. On each occasion the skim-milk bread rose slowly, requiring two or three hours more than the other. The bread mixed with water gave a somewhat whiter and lighter loaf than that mixed with skim milk, but all the bread showed a fairly uniform texture, and doubtless would have been generally conceded to be of a high grade.

The loaves were cut up, dried at a temperature of 50° to 70° C., ground, and analyzed by the usual methods.[1] The results of the analyses are shown in Tables 36 and 37. In general the protein has been calculated throughout this bulletin by the use of the usual factor 6.25. It is probable, however, that the protein of bread is more nearly represented by nitrogen multiplied by 5.7.[2] Inasmuch, however, as the data recorded are more for comparison with each other than for comparison of actual quantities of protein, it makes little difference which factor is used. In Tables 36 and 37, however, the protein is estimated by the factor 5.7 as well as by 6.25, and two values are given for carbohydrates corresponding to the two values for protein.

TABLE 36.—*Composition of fresh substance of bread mixed with water and with skim milk.*

Laboratory number.	Kind of bread.	Water.	Protein.		Fat.	Carbohydrates.		Ash.	Heat of combustion.
			N × 6.25.	N × 5.7.		Taking protein as N×6.25.	Taking protein as N×5.7.		
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
6115	Water bread	40.40	8.97	8.09	1.13	48.59	49.47	0.91	2,683
6118	do	40.07	8.81	8.04	1.05	49.12	49.89	.95	2,704
6190	do	37.84	9.02	8.21	1.03	51.35	52.16	.76	....
	Average	39.44	8.93	8.11	1.07	49.69	50.51	.87	....
6116	Skim-milk bread	39.66	9.84	8.95	.75	48.58	49.47	1.17	2,668
6119	do	38.63	9.80	8.95	1.10	48.85	49.70	1.62	2,752
6191	do	35.62	10.29	9.35	.98	52.02	52.97	1.08	....
	Average	37.97	9.98	9.09	.94	49.82	50.71	1.29	....

---

[1] U. S. Dept. Agr., Division of Chemistry Bul. 46, revised.

[2] See discussion of this subject in U. S. Dept. Agr., Division of Chemistry Bul. 13, pt. 9, pp. 1171, 1192.

TABLE 37.—*Composition of water-free substance of bread mixed with water and with skim milk.*

Laboratory number.	Kind of bread.	Protein.		Fat.	Carbohydrates. [a]		Ash.	Heat of combustion.
		N × 6.25.	N × 5.7.		Taking protein as N × 6.25.	Taking protein as N × 5.7.		
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
6115	Water bread	15.05	13.74	1.90	81.52	82.83	1.53	4,502
6118	do	14.70	13.39	1.75	81.97	83.28	1.58	4,511
6190	do	14.50	13.22	1.67	82.60	83.88	1.23	....
	Average	14.75	13.45	1.77	82.03	83,33	1.45	....
6116	Skim-milk bread	16,31	14.88	1.25	80.50	81.93	1.94	4,423
6119	do	15.97	14.53	1.80	79.57	81.02	2.65	4,456
6191	do	15.97	14.53	1.21	81.13	82.57	1.69	....
	Average	16.09	14.65	1.42	80.40	81.84	2.09	....

[a] Assuming protein = N × 5.7.

By reference to the preceding tables it will be seen that the bread made with water contained slightly less dry matter than that made with skim milk. In the fresh bread there is but little difference in the content of carbohydrates, but as regards protein the bread from dough mixed with skim milk contains 1 per cent more than that from dough mixed with water. The difference in the protein content of the bread made in the two ways is still more noticeable when water-free substance is considered. Here there was 14.75 per cent of protein in the bread from dough mixed with water as compared with 16.08 per cent in that from dough mixed with skim milk.

THE DIGESTIBILITY IN PEPSIN SOLUTION OF BREAD MADE WITH SKIM MILK AND WITH WATER.

The only experiments upon the digestibility of bread made by use of skim milk which have come to our notice are those by Repsteiner and Spirig.[1] Two tests, each of three days' duration, were made. The diet consisted of skim-milk bread, butter, and tea. In the first experiment 1,780 grams of bread was consumed, containing 39.2 grams of nitrogen, 33 grams of fat, and 1,098 grams of carbohydrates. The feces contained 53 grams of dry matter, with 2.3 grams of nitrogen and 4.7 grams of fat. In the second experiment 1,533 grams of dry matter in the form of bread was eaten. This contained 343 grams of nitrogen, 267 grams of fat, and 961 grams of carbohydrates. There was excreted in the feces 59 grams of dry matter, containing 3.8 grams of nitrogen and 8.7 grams of fat. No estimate of the amount of carbohydrates in the feces is given.

According to these results (as usually estimated) about 96.5 per cent of the nitrogen and 95 per cent of the fat were assimilated, values which are lower than those obtained in our experiments with bread in a mixed diet. However, as has been previously noted (see p. 15), there appears to be considerable difference between the digestibility of bread when eaten alone and when eaten in combination with other food.

---

[1] Korbl. Schweiz. Aerzte, 25, pp. 705–710.

For the purpose of studying the relative digestibility of the protein in breads made with skim milk and with water, artificial digestion experiments were carried on by the authors, using a pepsin solution in the manner previously described. As will be seen, no particular difference in the digestibility of the protein of the two kinds of bread was found by the method followed. The results obtained were as follows:

TABLE 38.—*Digestibility of the protein of water bread and skim-milk bread in pepsin solution.*

Laboratory number.	Kind of bread.	Coefficients of digestibility.
		Per cent.
6115	Water bread	95.62
6118	.....do	93.79
6190	.....do	96.53
	Average	95.31
6116	Skim-milk bread	94.32
6119	.....do	94.10
6191	.....do	96.25
	Average	94.89

The experiments here reported upon the composition and digestibility of skim-milk bread are not sufficient in extent to serve as a basis for definite conclusions. They do, however, appear to substantiate the opinion expressed by the authors, that skim-milk bread contains more protein than water bread. As regards the digestibility of the two there seems to be little difference. Therefore, other things being equal, it appears that the body would obtain more digestible protein from bread containing the larger amount, i. e., from skim-milk bread.

The practice of using skim milk in the making of bread is said to be quite prevalent in some sections. That the custom does not become more general must be due to a lack of appreciation of the food value of skim milk.

LOSSES IN BREAD MAKING.

Several experiments have been carried on in connection with investigations made in cooperation with the United States Department of Agriculture upon the loss of materials in bread making.[1] The following experiment was made in order to compare the losses in making bread by the use of skim milk and by the use of water in the preparation of the dough. All the materials used and the bread made were weighed and analyzed. It is thus possible to calculate the sum of nutrients in the various ingredients of the dough, and compare this amount with the total amount of nutrients found in the baked breads. The composition of the different materials used is shown in the following table:

---

[1] U. S. Dept. Agr., Office of Experiment Stations Buls. 35, 52, and 67.

TABLE 39.—*Composition of materials used in making bread.*

Laboratory number.	Materials.	Water.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion determined.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
6113	Flour	12.45	13.44	1.36	72.18	0.57	....
6189	.....do	11.70	13.31	1.44	73.05	.50	....
6114	Skim milk	89.16	3.75	.40	5.92	.77	515
6117	.....do	90.29	3.63	.12	5.30	.66	454
6188	.....do	90.29	3.88	.36	4.68	.79	469
	Yeast	65.10	11.70	.40	21.00	1.80	625

Three comparisons of the loss of nutrients in mixing bread with water and with skim milk were made. In each case the flour, salt, sugar, lard, and yeast used in the two sorts of bread were the same. The only variation was in the liquid used to mix the dough. The amount of the several materials used, the weight of the resulting bread, and the total quantity of the several nutrients in the different ingredients and in the resulting bread are shown in the following table:

TABLE 40.—*Weights and total nutrients of materials used and of bread made.*

	Weight of ingredients.	Total dry matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
Water bread No. 6115:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Flour No. 6113	782.4	684.99	105.15	10.64	564.74	4.46	3,074.0
Salt	8.3	8.30	....	....	....	8.30	....
Sugar	31.2	31.20	....	....	31.20	....	122.3
Lard	14.0	14.00	....	14.00	....	....	133.2
Yeast	4.4	1.53	.51	.02	.92	.08	2.8
Total	....	740.02	105.66	24.66	596.86	12.84	3,332.3
Bread	1,164.0	693.67	104.41	13.15	565.52	10.59	3,122.8
Losses	....	46.35	1.25	11.51	31.34	2.25	209.5
Skim-milk bread No. 6116:							
Flour No. 6113	752.4	658.72	101.12	10.22	543.09	4.29	2,956.2
Salt	9.4	9.40	....	....	....	9.40	....
Sugar	26.0	26.00	....	....	26.00	....	101.9
Lard	9.6	9.60	....	9.60	....	....	91.3
Yeast	3.6	1.26	.42	.01	.76	.07	2.3
Milk No. 6114	523.0	56.70	19.61	2.09	30.97	4.03	269.3
Total	....	761.68	121.15	21.92	600.82	17.79	3,421.0
Bread	1,210.8	730.56	119.16	9.14	588.08	14.18	3,230.9
Losses	....	31.12	1.99	12.78	12.74	3.61	190.1
Water bread No. 6118:							
Flour No. 6113	876.0	766.94	117.74	11.91	632.30	4.99	3,441.8
Salt	9.0	9.00	....	....	....	9.00	....
Sugar	24.4	24.40	....	....	24.40	....	95.7
Lard	20.8	20.80	....	20.80	....	....	197.8
Yeast	4.4	1.53	.51	.02	.92	.08	2.8
Total	....	822.67	118.25	32.73	657.62	14.07	3,738.1
Bread	1,322.6	792.50	116.53	13.84	649.64	12.49	3,475.2
Losses	....	30.17	1.72	18.89	7.98	1.58	262.9
Skim-milk bread No. 6119:							
Flour No. 6113	886.4	776.04	119.13	12.06	639.80	5.05	3,482.7
Salt	15.0	15.00	....	....	....	15.00	....
Sugar	25.8	25.80	....	....	25.80	....	101.2
Lard	23.2	23.20	....	23.20	....	....	220.7
Yeast	3.9	1.37	.46	.02	.82	.07	2.4
Milk No. 6117	575.3	55.69	20.88	.69	30.32	3.80	261.1
Total	....	897.10	140.47	35.97	696.74	23.92	4,068.1
Bread	1,426.0	874.30	139.66	15.77	695.69	23.18	3,924.3
Losses	....	22.80	.81	20.20	1.05	.74	143.8

TABLE 40.—*Weights and total nutrients of materials used and of bread made*—Cont'd.

	Weight of ingredients.	Total dry matter.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion.
Water bread No. 6190:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Flour No. 6189	1,287.3	1,136.60	171.33	18.54	940.30	6.44	5,098.6
Salt	10.0	10.00	....	....	....	10.00	....
Sugar	250.9	25.00	....	....	25.00	....	98.0
Lard	15.0	15.00	....	15.00	....	....	142.7
Yeast	5.0	1.75	.59	.02	1.05	.09	3.1
Total	....	1,188.35	171.92	33.56	966.35	16.53	5,342.4
Bread	1,864.0	1,158.60	168.12	19.19	957.13	14.16	5,172.6
Losses	....	29.75	3.80	14.37	9.22	2.37	169.8
Milk bread No. 6191:							
Flour No. 6189	1,240.6	1,095.45	165.12	17.86	906.27	6.20	4,914.0
Salt	10.0	10.00	....	....	....	10.00	....
Sugar	25.0	25.00	....	....	25.00	....	98.0
Lard	15.0	15.00	....	15.00	....	....	142.7
Yeast	5.0	1.75	.59	.02	1.05	.09	3.1
Milk No, 6188	800.0	77.68	31.04	2.88	37.44	6.32	375.2
Total	....	1,224.88	196.75	35.76	969.76	22.61	5,533.0
Bread	1,870.0	1,203.80	192.44	18.34	972.81	20.21	5,402.4
Losses	....	21.08	4.31	17.42	a3.05	2.40	130.6

a Gain.

It will be seen that in each case there was a loss of dry matter in the baking. This loss falls chiefly upon the fats and carbohydrates. The loss of carbohydrates may be readily understood, since they furnish food for the yeast plant, being in part converted into carbonic-acid gas and alcohol, in which form they are expanded by the heat of cooking. The loss of fat is not so readily explained. In fact, it is not improbable that this loss is not so large as it appears to be, but that in the process of bread making the starch and dextrin so inclose the fat that it is not removed by the usual extraction with ether.[1] Other explanations have been suggested.[2] That there is a small loss of fat is indicated, however, by a slightly greater loss of energy than would be accounted for by the loss of carbohydrates, as is pointed out by Voorhees.[3]

The results agree in the main with those previously reported by other investigators, and are here given for the purpose of placing the results thus far obtained upon record. It is expected that these, as well as most of the other data reported in this bulletin, can be combined later with the results of other work now in progress for more complete discussion.

---

[1] Weibull, Experiment Station Record, 5 (1894), p. 520. Also Voorhees, U. S. Dept. Agr., Office of Experiment Stations Bul. 35.

[2] See the discussion on this subject in U. S. Dept. Agr., Office of Experiment Stations Bul. 67.

[3] U. S. Dept. Agr., Office of Experiment Stations Bul. 35, p. 17.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON THE FOOD AND NUTRITION OF MAN—Continued.

Bul. 55. Dietary Studies in Chicago in 1895 and 1896. Conducted with the Cooperation of Jane Addams and Caroline L. Hunt, of Hull House. Reported by W. O. Atwater and A. P. Bryant. Pp. 76. Price, 5 cents.

Bul. 56. History and Present Status of Instruction in Cooking in the Public Schools of New York City. Reported by Mrs. Louise E. Hogan, with an introduction by A. C. True, Ph. D. Pp. 70. Price, 5 cents.

Bul. 63. Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body. By W. O. Atwater and E. B. Rosa. Pp. 94. Price, 10 cents.

Bul. 66. The Physiological Effect of Creatin and Creatinin and Their Value as Nutrients. By J. W. Mallet. Pp. 24. Price, 5 cents.

Bul. 67. Studies on Bread and Bread Making. By Harry Snyder and L. A. Voorhees. Pp. 51. Price, 10 cents.

Bul. 68. A Description of Some Chinese Vegetable Food Materials and Their Nutritive and Economic Value. By W. C. Blasdale. Pp. 48. Price, 10 cents.

Bul. 69. Experiments on the Metabolism of Matter and Energy in the Human Body. By W. O. Atwater and F. G. Benedict, with the cooperation of A. W. Smith and A. P. Bryant. Pp. 112. Price, 10 cents.

Bul. 75. Dietary Studies of University Boat Crews. By W. O. Atwater and A. P. Bryant. Pp. 72. Price, 5 cents.

Bul. 84. Nutrition Investigations at the California Agricultural Experiment Station, 1896–1898. By M. E. Jaffa. Pp. 39. Price, 5 cents.

FARMERS' BULLETINS.

Bul. 23. Foods: Nutritive Value and Cost. By W. O. Atwater. Pp. 32.
Bul. 34. Meats: Composition and Cooking. By C. D. Woods. Pp. 29.
Bul. 74. Milk as Food. Pp. 39.
Bul. 85. Fish as Food. By C. F. Langworthy. Pp. 30.
Bul. 93. Sugar as Food. By Mary H. Abel. Pp. 27.
Bul. 112. Bread and the Principles of Bread Making. By Helen W. Atwater. Pp. 38.

SEPARATES.

Food and Diet. Reprinted from Yearbook of Department of Agriculture for 1894. Pp. 44.

Foods for Man. Reprinted from Yearbook of Department of Agriculture for 1897. Pp. 7.

Some Results of Dietary Studies in the United States. By A. P. Bryant, Office of Experiment Stations. Reprinted from Yearbook of Department of Agriculture for 1898. Pp. 14.